IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION	)	
	)	
Plaintiff,	)	
	)	
v.	)	C.A. No. 06-738 (SLR)
	)	
HEWLETT-PACKARD COMPANY,	)	**REDACTED -**
	)	**PUBLIC VERSION**
Defendant.	)	

VOLUME I OF II
APPENDIX OF EXHIBITS TO
POLAROID'S OPENING BRIEF IN SUPPORT OF ITS MOTION TO PRECLUDE
HEWLETT-PACKARD FROM RELYING ON UNTIMELY PRODUCED DISCOVERY

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CERTIFICATE OF SERVICE

I, the undersigned, hereby certify that on June 2, 2008, I electronically filed the foregoing with the Clerk of the Court using CM/ECF, which will send notification of such filing(s) to the following:

William J. Marsden, Jr.
FISH & RICHARDSON P.C.

I also certify that copies were caused to be served on June 2, 2008 upon the following in the manner indicated:

BY E-MAIL

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EXHIBIT 1

"Blumenfeld, Jack" <JBlumenfeld@MNAT.com> 01/31/2008 01:48 PM	To	"Russell Levine" <rlevine@kirkland.com>, "C. Graham Gerst" <ggerst@kirkland.com>, <Skinnerm@kirkland.com>, "Maria Meginnes" <MMeginnes@kirkland.com>
	cc	
	Subject	FW: Polaroid v. HP

From: William Marsden [mailto:marsden@fr.com]
Sent: Thursday, January 31, 2008 1:40 PM
To: Blumenfeld, Jack
Subject: RE: Polaroid v. HP

Jack - Thanks for your message. I think we should be able to reach agreement on the scheduling issues. I'm checking the logistics of getting it all done by 2/8. For some of the topics, we have not yet identified a witness and therefore have not been able to check witness availability. I will also inquire re referral to the Magistrate Judge. Wm.

From: Blumenfeld, Jack [mailto:JBlumenfeld@MNAT.com]
Sent: Thursday, January 31, 2008 7:28 AM
To: William Marsden
Subject: RE: Polaroid v. HP

Thanks, William. We are willing to extend the expert discovery dates as you have suggested, as long as we can complete the outstanding discovery loose ends promptly -- we propose by next Friday, February 8. Also, given that summary judgment motions are due May 16, we will need to work cooperatively so that expert depositions can be completed in an orderly fashion by May 9.

Jack

From: William Marsden [mailto:marsden@fr.com]
Sent: Wednesday, January 30, 2008 4:25 PM
To: Blumenfeld, Jack
Subject: RE: Polaroid v. HP

Jack - We are considering your request for additional witness on the 30(b)(6) topics you identified during our telephone call this morning, including the topics in Polaroid's 15th 30(b)(6) notice which we believe was not timely noticed. We are also considering Polaroid's request for 5 additional hours of deposition time. By our calculations, Polaroid is already close to exhausting its deposition hours. As you know, we have also requested that Polaroid provide additional information and identification of source code to comply with Judge Robinson's order of December 5. It is also possible that HP will be producing some additional documents in response to Polaroid's deposition notices and letters.

If HP agrees to provide additional witnesses and consents to Polaroid's request for additional deposition time, we would also like to modestly extend the expert report and deposition schedule to reflect the fact that fact discovery has been extended. We propose moving the dates for expert reports by two weeks and the close of expert discovery by nine days, as follows:

Initial Expert Reports: 3/14
Responsive Expert Reports: 4/18
Close of Expert Discovery: 5/9

This would not affect any of the other dates in the current scheduling order. Please advise whether Polaroid is willing to agree to these extensions in exchange for extending the fact discovery period to complete the discrete fact discovery loose ends we have discussed.

Thanks.

Wm.

778-8401

From: Blumenfeld, Jack [mailto:JBlumenfeld@MNAT.com]
Sent: Tuesday, January 29, 2008 5:13 PM
To: William Marsden
Subject: Polaroid v. HP

William -- I just left you a voicemail message. Can you give me a call to discuss some discovery issues? Thanks.

Jack

351-9291

EXHIBIT 2

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION Plaintiff, v. HEWLETT-PACKARD COMPANY, Defendant.	C.A. No. 06-783 (SLR)

SUPPLEMENTAL EXPERT REPORT OF DR. RANGARAJ RANGAYYAN

I, Dr. Rangaraj Rangayyan, submit this supplemental report on behalf of the defendant Hewlett-Packard Company ("HP").

I. INTRODUCTION

1. My background and credentials in digital image processing and contrast enhancement have been previously described in detail and set forth in HP's "Expert Report of Dr. Rangaraj Rangayyan" of April 14, 2008 ("HP's Expert Report on Invalidity") (see paragraphs 1-12).

2. It is my understanding that on April 14, 2008, concurrently with the submission of HP's Expert Report on Invalidity, Polaroid Corporation ("Polaroid") submitted the expert report of Dr. Peggy Agouris ("Polaroid Expert Report") regarding U.S. Patent No. 4,829,381 (the '381 patent").

3. I have been asked by HP to review Polaroid's Expert Report.

4. I have reviewed Polaroid's Expert Report and provide this supplemental expert report on invalidity of the '381 patent taking into account certain of the allegations, analysis and conclusions contained in Polaroid's Expert Report.

5. In rendering my opinion, I have reviewed at least the documents and materials attached to or described in Exhibit A as well as those documents and materials previously identified in Exhibit B of HP's Expert Report on Invalidity.

6. In view of the allegations, analysis and conclusions presented in Polaroid's Expert Report, I remain of the opinion that, for the reasons described in my original report, the '381 patent is not valid.

7. As described in further detail below, in Polaroid's Expert Report, Dr. Agouris expresses certain opinions regarding the alleged scope of the asserted claims. In light of those assertions, I submit in this report additional analysis supporting my conclusion that the '381 patent is invalid.

8. As with my initial report, I may use this supplemental report, its exhibits, and documents and information written herein in support, or as necessary at any testimony concerning the subjects disclosed in this report or the state of the art of image processing. In addition, I may use demonstrative devices, including audio or visual aids and schematic representations, animated or otherwise, to illustrate my analysis of the '381 patent or any other technology such as that described in documents referred to, and/or analysis presented, herein.

II. THE POLAROID EXPERT REPORT

9. In reviewing the Polaroid Expert Report, I was not asked to, and did not formulate opinions regarding the accuracy or quality (or lack thereof) of Polaroid's application of various assertions and arguments to the alleged infringement of the '381 patent by certain of HP's

products. My analysis was limited to understanding – as best one could – Polaroid's assertions regarding the scope of the asserted claims and then assessing the validity of the asserted claims in light of the scope asserted by Polaroid. Nothing in this report should, therefore, be taken as an assertion that I, in any way, agree with or find accurate the infringement analysis presented in Polaroid's Expert Report, including the analysis regarding the scope of the asserted claims. I have simply analyzed the validity of the asserted claims taking the claim scope asserted by Polaroid as a given – without any analysis as to whether their scope is appropriate. Likewise, I have not been asked to, and I have not, taken up the task of commenting on the accuracy of any of the technical specifics detailed in Dr. Agouris' report. The absence of any commentary with regard to any technical specifics is not intended to, and should not, be taken as an indication of my agreement with such statements.

A. Polaroid's General Statements Regarding The Scope Of The '381 Patent

10. In the course of her report, Dr. Agouris makes certain general statements regarding the alleged scope of the asserted claims of the '381 patent. As detailed below, certain of those assertions, if credited, would render the asserted claims invalid for reasons beyond those asserted in my initial report. Having had an opportunity to review that report, I offer this supplementation detailing the impact of certain of Polaroid's general statements regarding the alleged scope of the claims as it relates to what was known in the art prior to the alleged priority date of the '381 patent.

11. The Polaroid Expert Report describes the '381 patent as selecting a group of pixels to average in accordance with the teachings of Digital Image Processing, Gonzalez, R. and Wintz, P. (Addison-Wesley Pub Co, 1987). (Polaroid Expert Report, page 11). Specifically,

Polaroid contends that the '381 patent selects the group of pixels by defining a window of pixels that includes the pixel to be transformed. Polaroid cites the second edition of the Digital Image Processing text book as describing the type of averaging used by the '381 patent.

12. To the extent that Polaroid argues that the scope of any element of the asserted claims covers the averaging performed by the '381 patent, the earlier edition of the same Digital Image Processing text book, published in 1977, teaches this averaging (i.e. utilizing a block average on the window of pixels with the pixel being transformed at the center). *Compare* Polaroid Expert Report, page 11 with Digital Image Processing text book of 1977 or 1987. (Gonzalez (1977), pages 136-137 and Gonzalez (1987), pages 158-163).

13. Polaroid describes all the accused HP products as performing the following on a pixel-by-pixel basis: taking an average of the surrounding pixels, comparing the individual pixel value to the average of the surrounding pixel values, and then altering the individual pixel value according to a predetermined algorithm, with the goal being to improve the contrast within a particular region. (Polaroid Expert Report, page 13).

14. To the extent that Polaroid argues that the scope of any of the asserted claims is coextensive with the above description, such a claim would be invalid.

15. The above-described functionality of the '381 patent was well-known prior to the time of filing the '381 patent. This is how many contrast enhancement transformations work. For example, as described in my initial report, each of Rangayyan, Richard, Chen, Gonzalez, Lee, Wang and Narendra performs this functionality. Each of these references describes pixel operations which perform transformation on a pixel-by-pixel basis. Each of these references takes an average of surrounding pixels and compares the pixel value being processed to this

average. Then, the pixel value being processed is transformed using a predetermined algorithm taught by the reference.

16. Polaroid describes the accused HP products as: defining transformation curves based on a power law function; calculating an average luminance value for each pixel as a function of the pixel being processed and a neighborhood of pixels; and generating a new enhanced image using the transformation curves, the average values and the original value of the pixel. (Polaroid Expert Report, page 16).

17. To the extent that Polaroid argues that the scope of any of the asserted claims is coextensive with the above description, such a claim would be invalid as these functionalities, were all, likewise, well-known prior to the time of filing of the '381 patent.

18. For example, Wang (1983) teaches defining transformation curves based on power-law functions. Wang describes two power-law transformations in Equation (5-3). (Wang, page 373). Wang further describes how the average level in the neighborhood of the pixel being processed may be incorporated into the power-law transformation. (Id.). Wang uses the power-law function, the average value and the pixel being processed to generate a new enhanced image. As illustrated by Fig. 5-1(e) and 5-2(i), the power-law functions of Wang produces transformation curves like those produced by the algorithms detailed in the '381 patent. (Wang, pages 372-373). Furthermore, the Okada reference (1984) cited during the prosecution of the '381 patent teaches several power-law gamma-correction functions in which the value of gamma is determined based upon an average picture level.

B. Specific Theories Advanced by Polaroid Regarding '381 Claim Scope That Impact The Validity of The Asserted Claims

19. In addition to the generalizations described above, in its Expert Report, Polaroid for the first time advances certain specific theories regarding the alleged scope of the asserted claims. Certain of those theories, if credited, would render the asserted claims invalid for reasons beyond those asserted in my initial report. Having had an opportunity to review that report, I offer the supplemental analysis in Sections III through VII, which detail the impact of certain of Polaroid's theories as they relate to what was known in the art prior to the alleged priority date of the '381 patent. In those Sections, I analyze the impact of the following assertions made in Polaroid's Expert Report:

Polaroid now asserts that the claims at issue cover systems and methods that employ algorithms that do not contain a ratio as written, because such algorithms can be reconstructed to contain a ratio and a "scaling variable."

20. Polaroid describes each of the transformation algorithms of the alleged HP LACE products as having the following characteristics: (1) a constant value referred to as "strength" and (2) use of the value of "strength" in an exponent: $2^{(y\text{-MID-TONE})*\text{Strength.}}$ (Polaroid Expert Report, pages 17-18).[1]

21. Polaroid asserts that "[s]trength as used in the exponent, *a*, is simply a number. (Polaroid Expert Report, page 27). Polaroid also asserts that the variable "strength" is allowed to take one of three values that are all integers, for example, 25, 50 or 75. (Polaroid Expert Report, pages 17-18).

22. Polaroid asserts that a number can be expressed as a combination of other numbers without changing its value. (Polaroid Expert Report, page 27).

23. Polaroid asserts that the number "strength" can be expressed as a combination of other numbers. Polaroid rewrites "strength" as a ratio of one number to another number: *D/Mid_Tone* (Id.). One of these numbers is set to a desired value and the other number is adjusted to maintain the original value of the "strength". Specifically, Polaroid defines the denominator of the ratio as a desired value within the dynamic range: *Mid_Tone*. The value of *D*, referred to as a "scaling variable," is adjusted by Polaroid so that the ratio *D/Mid_Tone* equals the original value of "strength." (Polaroid Expert Report, page 27).

24. In applying its theory, Polaroid adjusts *D* to any value necessary to maintain the original value of the number so expressed. Polaroid contends that the inclusion of this scaling factor not found in the original equation does not affect how the transformation is done, just the magnitude of its output. (Polaroid Expert Report, page 32).

25. By expressing a number as a ratio, Polaroid asserts that a number, such as an integer, may be written as a fraction: for example, 2 is the same as 4/2 or 6/3, or 8/4, or 256/128, or one of an infinite number of such ratios.

26. Polaroid, therefore, asserts that the claims at issue cover systems and methods that employ algorithms that do not contain a ratio as written, because such algorithms can be reconstructed to contain a ratio and a "scaling variable."

27. Using the logic of Polaroid's infringement theory described above, any number may be manipulated into the form of A_v/M, as any number may be expressed as a variable *D* divided by any value of *M* in the dynamic range so long as the value *D* is adjusted so as to keep the original value of the number the same. Furthermore, in order to have a ratio, one does not

[1] I have not been asked to – nor have I – examined any of the accused LACE algorithms used by HP. For purposes of this supplemental report I have taken Polaroid's characterization of those algorithms as a given without conducting any analysis of my own regarding the functioning or functionality of any HP product.

need any denominator in an equation of a transfer function. A denominator of a ratio may be constructed via any number in the equation – it does not need to originally exist in the equation.

28. Polaroid also asserts that the claims at issue cover systems and methods which employ any transfer function which can be algebraically manipulated to include the algebraic phrase *(Av/M-1) * D* after replacement of one or more values with a ratio and a "scaling variable." (Polaroid Expert Report, page 35). Polaroid rewrites the transfer function (*y-nMidtone*)**strength* to ((*y*/*nMidTone*)-1)**D* as follows: First, Polaroid expresses the variable "strength" as *D/nMidTone* as discussed above. The equation becomes: ((*y-nMidtone*)* *D/nMidTone*. Next, Polaroid multiplies the scaling variable *D* by (*y-nMidtone*) to produce: ((*y*D-nMidtone* D)/nMidTone*. This, then becomes:

*((y*D / nMidtone) - (nMidTone*D / nMidTone))*

Polaroid further transforms this equation into the following equation by using a common multiplier of the inserted variable *D* from both operands of the above minus operation:

*((y / nMidtone) -1) * D.*

In the above manipulation, the original equation (*y-nMidtone*)**strength* contains no ratio. Polaroid's manipulation brings in a nonexistent variable *D* to introduce a fictitious ratio. In order for this manipulation to produce the same result as the original equation, *D* must take on the variable value given by *D = nMidtone*strength.* Therefore, a ratio may be constructed from any number in the equation by employing any number of algebraic manipulations to the algorithm. (Id.).

29. As described below, applying the above arguments to the analysis of the prior art, it is clear that the prior art disclosed the use of a ratio as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

According to Polaroid, in gamma enhancement, any differences in the exponents of transfer functions are insubstantial.

30. According to Polaroid, in gamma enhancement, any differences in the exponents of transfer functions are insubstantial. Any variation in the exponent performs the same function in the transformation - selection of a transformation curve. (Polaroid Expert Report, page 29). Any variation in the exponent also achieves the same result: compressing or expanding the input pixel value. (Id.). As described below, applying the above argument to the analysis of the prior art, it is clear that the prior art disclosed the use of gamma function as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

Polaroid contends that the asserted claims cover both the implementation of an algorithm using software and/or hardwired circuits.

31. Polaroid contends that the asserted claims cover both the implementation of an algorithm using software and/or hardwired circuits equally, and therefore, for the purposes of meeting the limitations of the asserted claims, algorithms executed in software are the same as algorithms executed in hardware. (Polaroid's Expert Report, page 45). As described below, applying the above argument to the analysis of the prior art, it is clear that the prior art disclosed the use of software algorithms as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

Polaroid contends that there is no material difference between a non-repeating block averager and a repeating block averager

32. Polaroid contends that a non-repeating block averager in which an input pixel is part of only one average is insubstantially different from a repeating block averager in which the pixel is part of multiple averages. (Polaroid Expert Report, pages 70-71). Both types of averagers perform the same function of calculating an arithmetic mean of signals surrounding the input signal. (Id.). As described below, applying the above argument to the analysis of the prior

art, it is clear that the prior art disclosed the use of a non-repeating block averager as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

Polaroid contends that any algorithm that selects a transfer function based on the incoming pixel value, the average pixel value and the average divided by any value within the upper portion of the dynamic range performs the '381 algorithm

33. Polaroid also contends that the specific algorithm of the '381 patent under HP's construction is equivalently performed by an algorithm that selects a transfer function based on the incoming pixel value and the average pixel value signal, and further selects the transfer function based on the result of dividing the average value by a value within the dynamic range of the signal. (Polaroid Expert Report, pages 43-44). Polaroid further states that the value within the dynamic range does not need to be the maximum value of the dynamic range. (Polaroid Expert Report, page 44). Any value within the upper portion of the dynamic range selects the transfer function in substantially the same way. (Id.). Applying the above argument to the analysis of the prior art, it is clear that the prior art disclosed the use of values in the upper portion of the dynamic range of signal values to select the transfer function as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

Polaroid asserts that the claims at issue cover systems and methods which employ any algorithms having a number that may be represented as a constant used for controlling the selection of a transfer function

34. Polaroid also asserts that the claims at issue cover systems and methods which employ algorithms which can be manipulated into formats close to those described in the '381 patent in the following way: for any such algorithm which contains a number, that number may be rewritten to have a component which is variable. (Polaroid Expert Report, page 51). For example, the number "2" may be expressed as $1 + C$. (Id.). According to Polaroid, the value of C may be chosen to maintain the original value of the number "2" while controlling selection of

a transfer function. (Id.). This theory allows one to find any desired variable or constant within any other number in the transfer function. Polaroid argues that a constant in an equation may be replaced by a variable and vice versa. As described below, applying the above argument to the analysis of the prior art, it is clear that the prior art disclosed the use of a control parameter as claimed in the '381 patent and that, as a result – the '381 patent is invalid.

Summary of My Supplemental Assessment

35. In Section III below, I describe how, in light of Polaroid's theories, the Okada reference anticipates all asserted claims of the '381 patent.

36. In Section IV, I describe in detail the impact of the theories advanced by Polaroid in its Expert Report on the analysis of certain references discussed in my initial report – taking into account Polaroid's proposed claim constructions.

37. In Section V, I describe in detail how, in light of the theories advanced by Polaroid in its Expert Report, the Iida reference anticipates claims 1-2 and 7-8 of the '381 patent and how, in light of those theories, Iida in combination with any one of the Gonzalez algorithm, Gonzalez, Richard, Lee, Narendra, Sabri, Rangayyan, Chen and Wang teaches claims 3 and 9 of the '381 patent.

38. In Section VI, I describe in detail how, the theories advanced by Polaroid in its Expert Report impact the analysis of certain references discussed in my initial report - taking into account HP's proposed claim constructions.

39. In Section VII, I describe how the specification of the '381 patent fails to describe the claimed invention such that one of ordinary skill in the art could reasonably conclude that Polaroid had possession of the invention with the scope of claims as asserted by Polaroid.

III. THE OKADA REFERENCE IN VIEW OF POLAROID'S ASSERTIONS

40. In applying any of the references in this report to my assessment of invalidity of claims 1-3 and 7-9 of the '381 patent, I use the same understanding of the legal standard for anticipation and obviousness as in my original report.

41. As discussed in HP's Report on Invalidity, the Examiner rejected the claims of the '381 patent as unpatentable over United States Patent No. 4,489,349 to Okada ("Okada"). (see HP's Report On Invalidity, paragraphs 123-132).

42. In the rejection, the examiner stated:

> Okada discloses a video brightness control circuit having an average picture level of detector 20 which averages input picture information and provides a control signal to a variable correction circuit 10. The variable correction circuit operates on the input-output signal to vary the characteristic of the input-output signal as a function of the detected average picture level detector (see Fig. 2). Okada controls the relative brightness of the video signal such that the picture areas containing most of the picture information are corrected to give greater contrast. Although, Okada does not identically disclose all the element [sic] as recited in claims 1, 2, 8 and 9, Okada does provide a system which attempts to achieve the same results as the applicant. Both systems show an averaging circuit and a correction circuit which use the averaged information to produce an output which follows the slopes of the curves shown in Figure 2 of the present invention and Figure 2 of Okada.

43. Okada describes a gamma-correction circuit – a transfer function - that varies the output based on the input as a function of an average. (Okada, col. 5, lines 1-4). This transfer function uses a power law function of X^{γ}. (Okada, col. 2, lines 46-57). The value of γ is changed according to the average (APL). (Okada, col. 5, lines 16-32; Fig. 5).

44. Polaroid amended the claims of the '381 patent to avoid the disclosure of Okada. Specifically, Polaroid added to claim 7 the limitation of a ratio of the value of an average signal to a proportionate value of the dynamic range of the signals. (HP's Report On Invalidity,

paragraphs 129-130). To address the same issue, Polaroid added to claim 1 the limitation of a ratio of the value of an average signal to a value of the dynamic range of the signals. (Id.)

45. As I stated in my initial report:

> ....the '381 patent appears to have been allowed by the patent examiner because Okada does not explicitly disclose the language added to claims 1 and 7 of the '381 patent, i.e., a ratio of the value of an average signal to a value [proportionate] of the dynamic range of the signals ... (HP's Report On Invalidity, paragraph 130).

46. As detailed below, Polaroid's assertions that the claimed ratio need not be stated in an algorithm and that any algorithm that can be algebraically manipulated and supplemented to create the claimed ratio is covered by the patent, effectively read the ratio limitation used to overcome Okada out of the claims.

47. As discussed above, Polaroid now asserts that any number may be expressed as a ratio of the average over any value within the dynamic range. Thus, under Polaroid's theories, any number of an exponent may be expressed as a ratio to teach the exponent portion of the '381 algorithm as construed by Polaroid.

48. Furthermore, Polaroid contends that any differences in the exponent of transfer functions are insubstantial. (Polaroid Expert Report, page 32). Polaroid asserts that the gamma in any exponent performs the same function for the transformation - selection of a transformation curve. (Id.). Thus, any number in the exponent may select a transformation curve, and this number may be expressed as a ratio.

49. With the combination of any difference in the exponent being insubstantial and any number in the exponent being manipulated to provide the ratio, Polaroid's theories reduce the structure disclosed in the '381 patent to the generic structure of any standard gamma transfer function, $Y=X^{\gamma}$. Furthermore, because the ratio of the average over any value in the dynamic

range can be generated by the algebraic manipulation and the inclusion of a "scalar constant" (or variable), the exponent of such a transfer can be any gamma, γ.

50. Applying the theories in Polaroid's Expert Report described above to the analysis of Okada, it is clear that Okada teaches a transfer function having the ratio of the invention of the '381 patent. As described above, Okada teaches a transfer function having a power-law function X^{γ} and using an average value. Applying the same algebraic substitution and manipulations used by Polaroid in its Expert Report, this gamma γ and average value may be expressed via Polaroid's theories to teach the ratio of the '381 patent.

51. The value of γ in the transfer function of Okada is a number. Its value may vary between 0 and 3. It may also be a fractional number that is a ratio of two integers, such as 1/2, 1/3, 2/3, 3/2, 5/2, and so on. In accordance with Polaroid's definition of a number, the number, γ, may be expressed as a combination of other numbers without changing its value.

52. Furthermore, in accordance with Polaroid's manipulation of a number into a ratio, the value of γ may be expressed as a ratio based on the average. The transfer function of Okada receives the average value APL (directly comparable to A_v in the '381 patent) as input. The transfer function responsive to this average value produces the value γ for use as the exponent in the power law function X^{γ}. The average value is an input to this transfer function and available as a number to determine the exponent. Thus, this average is available as a number to use in the expression of gamma, γ, as a ratio.

53. According to Polaroid, the gamma of the transfer function may be expressed as a ratio of the value of an average to a value proportionate of the dynamic range. A fractional value of gamma, γ, may be expressed as a variable D times Av divided by a value M as Polaroid

contends in its Expert Report. The transfer function of Okada may be manipulated as follows: First, start with the equation:

X^{γ} where gamma γ is equal to a number.

Then, we may express gamma as a combination of other numbers by setting γ equal to a ratio of an average Av over a value M within the dynamic range.

$$X^{(Av/M)}$$

The value M may be set to a value within the dynamic range, such as to a midpoint value in the case of the '381 patent. Thus, M is available as a denominator. As the average Av is also used as an input to the transfer function to produce gamma, it is available as a numerator. Further, the ratio A_v/M in the exponent is multiplied by the scaling factor D:

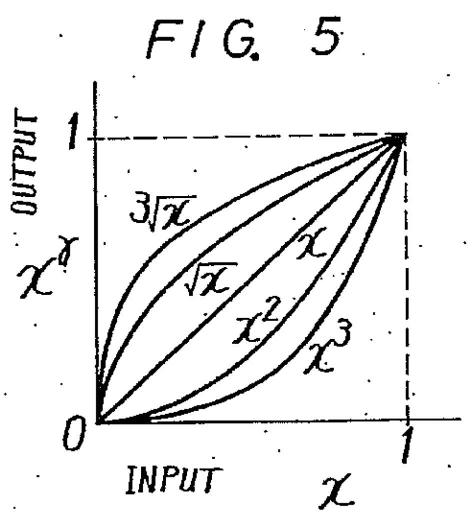
$$X^{(Av/M) \times D}$$

D is adjusted to a value to maintain the original value of the gamma. With M as a denominator and A_v as a numerator, the gamma of the transfer function of Okada may be expressed as the ratio of $\gamma = D \times A_v/M$. For example, if we have $\gamma=2/3$, and suppose that the APL value in the Okada method, which is similar to Av in the '381 patent, is 100. Suppose also that $M = 128$. Then, we could write $\gamma = D \times A_v/M = D \times 100/128$. In order for γ to retain its original value of $2/3$, we need only to let $D = 256/300$. Therefore, applying Polaroid's theories, Okada's method may be manipulated to include the ratio A_v/M as in the '381 patent.

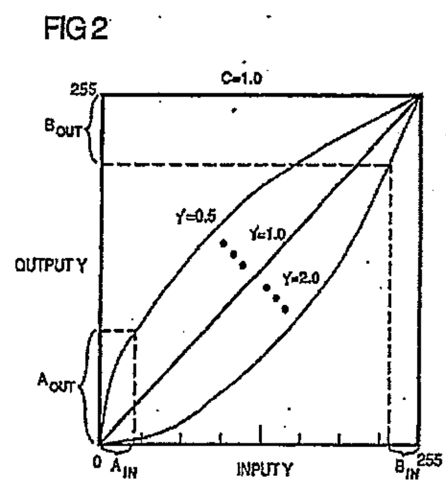
54. The ratio of A_v/M was the only element missing from Okada to anticipate claims 1 and 7 of the '381 patent. Under Polaroid's theories, an existing ratio is not required – any number will do. As demonstrated above under Polaroid's theories Okada teaches the only missing element - the ratio. Since, under Polaroid's theories, this ratio is now taught by, or is

inherently in, Okada , I believe that, if one were to credit Polaroid's theories, claims 1 and 7 of the '381 patent are anticipated by Okada.

55. With respect to claims 2 and 8, the Examiner also found during examination of the '381 patent that Okada discloses these claim elements. (see the Office Action of October 20, 1998 in the '381 file history). In accordance with the subject matter of these claims, Okada teaches algorithms that select a transfer function that results in higher contrast to pixels when an average pixel value indicates a low light condition and when an average pixel value indicates a high light condition. (Okada, col. 2, lines 30-53 and Fig. 2; col. 5 lines 15-33 and Fig. 5) Reproduced below is a comparison between Figure 5 from Okada and Figure 2 from the '381 patent:



Okada FIG. 5



'381 Patent FIG. 2

The similarity between the gamma transfer functions of Okada and those of the '381 patent is clear. Each of them produces the phenomenon of higher contrast under light and dark scene conditions. Therefore, as the Examiner concluded, I believe that applying the theories stated in

the Polaroid Expert Report Okada also anticipates these claim elements, and thus, the 381' patent is invalid with respect to these claims.

56. Okada further teaches the subject matter of claims 3 and 9. These claims are directed to the selection of the transfer function as a function of a determined constant, where increasing the determined constant increases the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function. Okada teaches a variable correction circuit that provides a control signal in response to the average of the input signal. (Okada, col. 4, line 60 to col. 5, line 4). The control signal supplies the determined constant to adjust the input-output characteristics in accordance with Figures 2 and 5. (Id., see also the gain control elements and signals of Figures 8, 13). By increasing the control signal, the amount of contrast enhancement is also increased. Therefore, I believe Okada anticipates these claim elements, and thus, these claims of the '381 patent are invalid.

IV. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION IN LIGHT OF POLAROID'S INFRINGEMENT CONTENTIONS AND CLAIM CONSTRUCTION

57. As previously stated, I understand that HP and Polaroid have proposed different constructions of the disputed claims and that the Court has not yet ruled on the proper interpretation of these claims. (HP's Expert Report on Invalidity, paragraph 134). I provide the following assessment of the novelty and obviousness of claims 1-3 and 7-9, on the assumption that the Court adopts Polaroid's proposed construction of the claims and Polaroid's theories for their proposed claim construction without myself having formed any opinion as to the accuracy of those constructions.

Assessment of Claim 7

58. Applying Polaroid's proposed claim constructions and its infringement theories, I believe that claim 7 of the '381 patent is anticipated by any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.[2]

59. Claim 7 contains a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

<u>A method for continuously enhancing . . . .</u>

60. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

61. In its Expert Report, Polaroid states that any method that transforms intensity values for each pixel in an image by processing one pixel at a time would perform the functionality of, and meet the limitations present in, the preamble. (Polaroid Expert Report, page 21).

62. Each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches this claim element as defined by Polaroid in its Expert Report.

63. For this claim element, Polaroid describes operations on a pixel-by-pixel basis. Such a pixel-by-pixel operation is referred to as a "pixel operator." A pixel operator is an algorithm designed to perform transformation on a pixel-by-pixel basis. That is, the algorithm

takes a single input pixel value and transforms it to a single output pixel value. The algorithm is applied to a series of input pixel values, one after another, to provide a corresponding set of output pixel values. For example, the algorithm of a pixel operator may be applied to each pixel in each rows and columns of pixels of an image to transform the entire image.

64. Each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches a pixel operator, and thus, teaches this claim element as follows.

65. Gonzalez describes a pixel operator *g(x.y)* that transforms the intensity of an input image into a new image by performing the algorithm of equation (4.2-14) at each pixel location *(x,y)*. (Gonzalez, page 159-160).

66. The Gonzalez algorithm describes a pixel operator in the form of a function "*FLEV*" that transforms, one at a time, each of the input pixel values of an array of pixel values for an image. (Gonzalez, Appendix A, page 388-392).

67. Richard describes pixel-by-pixel operations in which the processor receives a sequence of pixel values, transforms each pixel value one at a time, and outputs the corresponding transformed pixel value to provide an enhanced image. (Richard, col. 2, lines 15-34).

68. Lee describes algorithms in Equations (3), (4) and (5) that perform transformation on a pixel-by-pixel basis for an image represented by a two-dimensional array of pixels. (Lee, page 166). These algorithms are designed to take the input pixel $x_{i,j}$ – the brightness of the pixel at the location *(i,j)* in the two-dimensional array – and provide an enhanced value for that pixel, $x'_{i,j}$. (Id.). These algorithms are applied to each pixel from the two-dimensional array, one at a time, to provide an enhanced image.

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[2] I believe that claim 7 is also anticipated by Okada as described above.

69. Sabri describes pixel-by-pixel operations in which the processor takes as input a series of input pixel values, X_{nm}, performs transformation on each input pixel value and outputs a corresponding transformed value, Y_{ij}. (Sabri, FIGs. 1 and 2).

70. Rangayyan describes a set of pixel operators C, p' and p'' to transform an input pixel value p into a transformed output pixel value produced by p''. (Rangayyan, page 561). These pixel operations are performed successively on all pixels in the image. (Rangayyan, page 562).

71. Chen describes pixel-by-pixel operations in which the image improving device replaces each pixel value $I(i,j)$ with an improved pixel value $I'(i,j)$. (Chen, Abstract). Each resultant enhanced pixel value $I'(i,j)$ is stored at the corresponding pixel of the improved image. (Chen, col. 8, lines 6-19).

72. Narendra describes an algorithm or pixel operator in Equation (1) that performs transformation on a pixel-by-pixel basis. (Narendra, page 656). The image intensity at each point $I_{i,j}$ is transformed using this algorithm into a transformed intensity, $\hat{I}_{i,j}$, for that point. (Id.).

73. Wang describes several pixel operators performing contrast enhancement on each pixel, one at a time. In one example, Wang teaches the algorithm of Lee with equation (6-4). (Wang, page 376). In another example, Wang teaches the exponential-based algorithms illustrated in Equations (5-3). (Wang, page 373). These algorithms of Wang are designed to take an input pixel $g(x,y)$ at the coordinates (x,y) in a two-dimensional array and provide an enhanced value for that pixel, $g'(x,y)$.

...averaging the electronic information signals....

74. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

75. As described in my initial report, each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches averaging in accordance with Polaroid's claim construction. (HP's Expert Report on Invalidity, paragraphs 149-160).

...selecting one of a plurality of different transfer functions....

76. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

77. As described in my initial report, each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches this claim element in accordance with Polaroid's claim construction. (HP's Expert Report on Invalidity, paragraphs 161-172).

...transforming the electronic information signal...

78. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

79. As construed by Polaroid, the function that transforms the input signal is further selected as a function of the following ratio: *calculated intermediate value / a value within a range of values*. (HP's Expert Report on Invalidity, paragraphs 173-176).

80. According to Polaroid's theories in its Expert Report, a ratio may be constructed from a number. A denominator in a ratio or a divisor in a division operation does not need to exist in the transfer function. A number in the equation of the transfer function may be converted into a ratio by dividing it by a value, *M*, within the dynamic range. Then, the value *M* is adjusted by a scaling factor *D* to maintain the original value of the number. (Polaroid Expert Report, page 27).

81. Each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches a ratio of a calculated intermediate value over a value within a range of values. (HP's Expert Report on Invalidity, paragraphs 177-185). Each of these references does not require any type of manipulation, applying Polaroid's theories, to construct this ratio. Each of these references already teaches an existing ratio as previously discussed in HP's Expert Report on Invalidity. (Id.).

82. Applying Polaroid's theories to the prior art, any number in the equations of each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang can also be manipulated to provide the ratio of this claim element. [3]

83. For example: Narendra teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of intermediate value over any value

[3] I do not perform the manipulation of applying Polaroid's theories to each of Richard and Sabri. As stated in my initial report Richard and Sabri disclose the ratio, Av/M. Applying Polaroid's theories to each of Richard and Sabri, this ratio could be converted into the same ratio of Av/M having the different values or the same values.

within a range of values. The following transformation function uses the pixel value I_{ij} of the pixel being processed and a mean value M_{ij} to provide the improved pixel value $\hat{I}_{ij}$:

$$\hat{I}_{ij} = G_{ij}(I_{ij} - M_{ij}) + M_{ij} \quad \text{(see Narendra, p. 656, Equation (1)).}$$

G_{ij} is a gain factor. The local mean value M_{ij} is a mean value (e.g., calculated intermediate value) a group of pixels surrounding the pixel being processed. (Narendra, p. 65, first paragraph). The transformation function takes the difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}.

$$G_{ij} = \alpha \frac{M}{\sigma_{ij}}, \; 0 < \alpha < 1 \quad \text{(Id.)}$$

Here, σ_{ij} is the standard deviation of local pixel values, α is a gain factor and M is the global mean. According to Polaroid's theories, the gain factor may be expressed in terms of a ratio of a scaling factor D to a value within the dynamic range, M:

$$\text{Let } \alpha \frac{M}{\sigma_{ij}} = \frac{D}{\sigma_{ij} M_x} \quad \text{with } D = \alpha \times M \times M_x$$

M_x is set to a value within the dynamic range and D is a scaling factor adjusted to maintain the original value of the gain G_{ij}. By performing the following algebraic operations allowed by Polaroid's theories, the transfer function is manipulated to have a ratio of an intermediate calculated value (an average comparable to Av) over a value within a range of values:

$$\hat{I}_{ij} = (D/(\sigma_{ij} M_x)) \times (I_{ij} - M_{ij}) + M_{ij}$$

$$\hat{I}_{ij} = (D/\sigma_{ij}) \times (I_{ij}/M_x - M_{ij}/M_x) + M_{ij}$$

$$\hat{I}_{ij} = (D/\sigma_{ij})(I_{ij}/M_x) - (D/\sigma_{ij})(M_{ij}/M_x) + M_{ij}$$

The ratio M_{ij} / M_x is a ratio comparable to the ratio (Av/M) in the '381 patent. The value M_{ij} is the average value of the pixels surrounding the pixel being processed. The value M_x may be set to any value in the dynamic range. Therefore, on Polaroid's theories, Narendra teaches

transforming an input signal based on an equation having a number that may be manipulated into a ratio of the calculated intermediate value over any value within a range of values. On this additional basis, I confirm that, on Polaroid's theories, Narendra teaches this claim element.

84. Gonzalez uses a equation similar to that used in Narendra, therefore, applying Polaroid's theories, a number in Gonzalez may be manipulated into a ratio of the calculated intermediate value over any value within a range of values in the way described above. Therefore, on this additional basis, I confirm that, on Polaroid's theories, Gonzalez teaches this claim element.

85. Likewise, the equation of the Gonzalez algorithm includes a number that can be manipulated in a similar fashion to be expressed as a ratio of the calculated intermediate value over any value within a range of values. The Gonzalez algorithm computes a calculated intermediate value for a group of pixels using the following function, *SS:*

$$SS=(-1/GN) * \text{ALOG}\ (FH/T)$$

GN contains a value of 32, representing the maximum value of the dynamic range of the intended output device (in this case, a line-printer). *FH* represents the maximum gray level value of the group of pixels representing the input image. (Gonzalez, p. 453, line 4). *T* represents the minimum gray level of the group of pixels representing the input image (Gonzalez, p. 453, line 3). According to Polaroid's theories, the number from the ratio *FH/T* may be expressed in terms of a ratio that includes an average, a scaling factor *D* and a value within the dynamic range, *M*:

$$\text{Let } FH/T = D \times Av/M \text{ where } D = FH \times M/(T \times Av)$$

Therefore, the transfer function SS becomes:

$$SS=(-1/GN) * \text{ALOG}\ (D \times Av/M)$$

The ratio *Av /M* is a ratio comparable to the ratio (*Av/M*) in the '381 patent. The value *Av* is the average value of the pixels surrounding the pixel being processed. The value *M* may be set to any value in the dynamic range. Therefore, the Gonzalez algorithm teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of the intermediate calculated value over any value within a range of values. On this additional basis, I confirm that, on Polaroid's theories, the Gonzalez algorithm teaches this claim element.

86. Wang, similarly, teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of the intermediate value over any value within a range of values using Polaroid's theories. (Wang, p. 376, Eq. 6-4). By one example, Wang teaches the following algorithm of Lee which provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed, $g(x,y)$, and the computed local mean value, $m(x,y)$:

$$g'(x,y) = m(x,y) + k(g(x,y) - m(x,y)) \quad \text{(Wang, p. 376).}$$

The gain factor k is a number, which under Polaroid's theory may be expressed as a combination of other numbers. In accordance with Polaroid's theories, one can set $k = D/g(x,y)$ with $D = k \times g(x,y)$. Applying this value of k to the above equation results in:

$$g'(x,y) = m(x,y) + (D/g(x,y))\,(g(x,y) - m(x,y))$$

Then, we apply the following algebraic steps:

$$g'(x,y) = m(x,y) + D\,(1 - m(x,y)/\,g(x,y))$$

$$g'(x,y) = m(x,y) - D\,(m(x,y)/\,g(x,y) - 1) = m(x,y) - D\,(Av/M - 1)$$

The ratio $m(x,y)/\,g(x,y)$ is a ratio like the ratio (*Av/M*) in the '381 patent. The value $m(x,y) = Av$ is the average value of the pixels surrounding the pixel being processed. The value $g(x,y) = M$ is a pixel value and therefore, by definition, is a value within the dynamic range. Therefore, on

Polaroid's theories, Wang teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of the intermediate calculated value over any value within a range of values.

87. As described above, equation (6-4) of Wang uses the algorithms taught by Lee. Therefore, the equation of Lee has a number that may be manipulated in a similar manner as described above for Wang. (Lee, Equations 4 and 5). Furthermore, Chen also uses the algorithm taught by Lee, and this can also be manipulated in the same manner. Therefore, on this additional basis, I confirm that, on Polaroid's theories, each of Chen and Lee teaches this claim element

88. Furthermore, Wang teaches another example of transforming an input signal based on an equation having a number that may be manipulated into a ratio of a calculated intermediate value over any value within a range of values using Polaroid's theories. In this example, Wang transforms an input signal using the following power-law transfer function:

$$g'(x, y) = g_{\min}\left[\frac{g_{\max}}{g_{\min}}\right]^{P(g(x,y))}$$

(Wang, page 373, Equation (5-3)).

The value $g(x,y)$ is the input value which is transformed by the power-law function of $[g_{max}/g_{min}]^{P(g(x,y))}$ to produce the enhanced pixel value g'(x,y). $P(g(x,y))$ is a value of a function applied to the pixel value at (x,y), in this example, the cumulative distribution function referred to as the CDF. The CDF is the integral of the probability density function (PDF) up to the value specified. This means that the CDF is given by the ratio defined as [total number of all pixels in the given image having the grayscale value up to and including $g(x,y)$] divided by [the total number of pixels in the given image]. (Wang, page 373). So, we have a power-law function that includes an exponent raised to the power of the ratio produced by this CDF. Although the CDF

already produces a ratio of an intermediate calculated value over a value within a range of values, this ratio is also a number than may be expressed as a combination of other numbers in accordance with Polaroid's theories. The number *P(g(x,y))* may be expressed in terms of a ratio of a value *Av* to a value within the dynamic range, *M*, along with a scaling factor *D*:

Let *P(g(x,y)) = D*Av/M* where *D* is adjusted to maintain the original value of *P(g(x,y))*. For example, *D* may be set to *M/Av * P(g(x,y))*. Then, the transfer function becomes:

$$g'(x, y) = g_{\min}\left[\frac{g_{\max}}{g_{\min}}\right]^{Av/M * D}$$

Therefore, on Polaroid's theories, this equation of Wang also teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of the calculated intermediate value over any value within a range of values.

89. Rangayyan teaches transforming an input signal based on an equation having a number that, using Polaroid's theories, may be manipulated into a ratio of the intermediate calculated value over any value within a range of values (see Rangayyan, p. 561, Section C, Contrast Enhancement). Rangayyan computes a contrast measure *C* using the input pixel value, *p*, and the average value, *a*, of the values of the pixels surrounding *p*:

$$C = \frac{|p-a|}{(p+a)}$$ (Rangayyan, p.561, col. 2).

Considering the equation for *C* above, we have

$$C = |(p-a)| / (p+a) = |p/(p+a) - a/(p+a)|.$$

It is evident that this formula has the ratio: $a / (p + a)$, which comprises an average of surrounding pixel values over a value within a range of values, $(p + a)$. Therefore, on Polaroid's

theories, Rangayyan teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value over a value within a range of values formed from a number in the equation.

90. For the reasons stated above in combination with those expressed in my initial report, I find that, in view of Polaroid's construction and Polaroid's theories applying such construction, each and every element of claim 7 can be found in each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang, and that, therefore, claim 7 is anticipated, as that concept has been explained to me, by each one of those references.

Assessment of Claim 8

91. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

92. As stated in HP's Expert Report on Invalidity, paragraph 188, claim 8 requires a method having all the elements of claim 7 and the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition.

93. In its Expert Report, Polaroid advances the theory that any algorithm that satisfies claim 7 and produces a graph that corresponds to the phenomenon described by this claim element would infringe this element.[4] Accordingly, then, under Polaroid's infringement

[4] As I previously stated: Nothing in this report should be taken as an assertion that I, in any way, agree with or find accurate the infringement analysis presented in Polaroid's Expert Report, including the analysis regarding the scope

theories, any algorithm that satisfies claim 7 and selects a transfer function that imparts higher contrast to pixels when a calculated intermediate value indicates a low light condition and when a calculated intermediate value indicates a high light condition teaches this claim element. As described above in paragraph 43, Okada teaches this graph, and thus teaches this claim element.

94. Furthermore, Wang teaches transfer functions designed to provide higher contrast to pixels when a calculated intermediate value[5] indicates a low light and when a calculated intermediate value indicates a high light condition. The non-linear transformations illustrated in Figure 5-1 teach methods to obtain higher contrast under low light and high light conditions. As the slope of the transfer function increases to values greater than 1, the transformation will increase the change in the transformed pixel value in low light and/or high light conditions. The non-linear transformations of Wang produce transformation results like the power-law functions of the '381 patent and Okada.[6] (see paragraph 54). Therefore, Wang teaches transfer functions to provide higher contrast to pixels when a calculated intermediate value indicates a low light and when a calculated intermediate value indicates a high light condition.[7]

Assessment of Claim 9

95. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

of the asserted claims. I have simply analyzed the validity of the asserted claims taking the claim scope asserted by Polaroid as a given – without any analysis as to whether it is appropriate.

[5] As described above, the calculated intermediate value of Wang includes an average.

[6] Also like U.S. Patent No. 4,394,688 to Iida described in further detail below in this report.

96. Under Polaroid's proposed claim construction, this claim recites a method having all the elements of claim 8 and claim 7, and the element that the transfer function is selected as a function of a chosen number, where increasing the chosen number increases the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function.

97. Under Polaroid's theories in its Expert Report explained above, this element can be met by any number in a transfer function so long as varying that number would change the amount of contrast enhancement applied to a pixel. Specifically, Polaroid states that any such number in a transfer function may be represented as a combination of two other numbers or a number with a variable. (Polaroid Expert Report, page 51). Based on this assumption, Polaroid concludes that a number of a transformation algorithm may be equated with the chosen number of *C* in the equation *(1 + C)* of the '381 patent's algorithm. (Id.).

98. Under Polaroid's theories, each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, and Wang contains, and thus teaches, a number that may be increased to increase the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function.[8]

99. Gonzalez teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Gonzalez teaches the following gain factor used in the transfer function:

$$A(x,y)=\frac{k\times M}{\sigma(x,y)} \text{ for } 0<k<1. \text{ (Gonzalez, p. 160).}$$

The value of k may be set between 0 and 1 to increase this gain factor, and therefore, the amount of contrast enhancement. Furthermore, any portion of k, according to Polaroid, may be used as

the constant to control the amount of contrast enhancement. For example, k may be set equal to $1 + C$, where C provides the constant used for control. Therefore, on Polaroid's theories, Gonzalez teaches a number that may be increased to increase the amount of contrast enhancement.

100. The Gonzalez algorithm teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. The Gonzalez algorithm transforms an input pixel, I, into an output pixel value $FLEV$ as follows:

$$FLEV = FH * \mathrm{EXP}(SS*(GN-I)) + 0.5$$ (Gonzalez, p. 454)

The value of 0.5, may be set, in accordance with Polaroid, to $k + C$, where C provides the constant for control and k is a value equal to $0.5 - C$. Likewise, FH may be set, in accordance with Polaroid, to $1 + C$. Therefore, on Polaroid's theories, the Gonzalez algorithm teaches a number that may be increased to increase the amount of contrast enhancement.

101. Richard teaches a number that on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Richard transforms an input signal using the function depicted as element 5 in Figure 1 having a gain factor k:

$$Y'_{ij} = Y_{ij} \times \frac{M_v}{M_g} \times k$$ (Richard, col. 2, ll. 21-25; Fig. 1).

The value of k is increased to increase the gain, and therefore, the amount of contrast enhancement. Furthermore, any portion of k, according to Polaroid's theory, may be used as the chosen number to control the amount of contrast enhancement. For example, k may be set equal to $1 + C$, where C provides the chosen number for control. Therefore, on Polaroid's theories, Richard teaches a number that may be increased to increase the amount of contrast enhancement.

102. Lee teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Lee transforms the input pixel by multiplying the difference of $(x_{i,j} - m_{i,j})$ by a gain k and adding the result to the local mean to provide the transformed pixel value $x'_{i,j}$:

$$x'_{i,j} = m_{i,j} + k(x_{i,j} - m_{i,j}) \quad \text{(Lee, p. 166, Equation (4)).}$$

The value of k may be increased to increase the gain, and therefore, the amount of contrast enhancement. Furthermore, any portion of k, according to Polaroid, may be used as the constant to control the amount of contrast enhancement. For example, k may be set equal to $1 + C$, where C provides the constant used for control. Therefore, on Polaroid's theories, Lee teaches a number that may be increased to increase the amount of contrast enhancement.

103. Sabri teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Sabri transforms an input signal using the transformation function, B_{ij}

$$Bij = \gamma ij + \left(1 - \frac{2\gamma ij}{R}\right)\phi ij \quad \text{(Sabri, col. 2, ll. 40-46).}$$

The value γij is a contrast enhancement factor made up of constants α and β, and a variable C_{ij}. This contrast enhancement factor may be increased to increase the gain, and therefore, the amount of contrast enhancement. Furthermore, any portion of γij, according to Polaroid, may be used as the constant to control the amount of contrast enhancement. For example, γij may be set equal to $1 + C$, where C provides the constant used for control. Therefore, on Polaroid's theories, Sabri teaches a number that may be increased to increase the amount of contrast enhancement.

104. Rangayyan teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Rangayyan uses the transformation function $C' = \sqrt{C} = C^{1/2}$ to increase the measured contrast C to the desired higher contrast value C'. If we change the power from ½ to 1/3, by increasing the number 2 to 3, we get a larger increase in C'. (Note that C and C' are less than 1.0.) Furthermore, the number 1/2, according to Polaroid, may be used as the chosen number to control the amount of contrast enhancement. For example, 1/2 may be set equal to $1/(1 + C_1)$ with C_1 as in the '381 patent, where C_1 provides the constant used for control. Therefore, on Polaroid's theories, Rangayyan teaches a number (C_1) that may be increased to increase the amount of contrast enhancement.

105. Chen teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. Chen uses the following function to replace each input pixel value $I(i,j)$ with an improved pixel value $I'(i,j)$:

$$I'(i,j) = G(i,j) \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)} \quad \text{(Chen, Abstract).}$$

$G(i,j)$ refers to a gain function that produces an output value to apply to the difference between the input pixel value and a mean of pixel values of neighboring pixels. The value of the gain $G(i,j)$ may be changed to control the amount of contrast enhancement. Furthermore, any portion of $G(i,j)$, according to Polaroid, may be used as the constant to control the amount of contrast enhancement. For example, a number from the value of $G(i,j)$ may be set equal to $1 + C$, where C provides the constant used for control. Therefore, on Polaroid's theories, Chen teaches a number that may be increased to increase the amount of contrast enhancement.

106. Narendra teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. In Narendra, the transformation function takes the

difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}.

$$G_{ij} = \alpha \frac{M}{\sigma_{ij}}, \quad 0 < \alpha < 1$$ (see Narendra, p. 656, Equation (1)).

The value of α may be set between 0 and 1 to increase this gain factor, and therefore, the amount of contrast enhancement. Furthermore, any portion of α, according to Polaroid, may be used as the constant to control the amount of contrast enhancement. For example, α may be set equal to $1 + C$, where C provides the constant used for control. Therefore, on Polaroid's theories, Narendra teaches a number that may be increased to increase the amount of contrast enhancement.

107. Wang teaches a number that, on Polaroid's theories, may be increased to increase the amount of contrast enhancement. In Equation (6-4), Wang teaches a gain factor k applied to the difference between an input pixel value and the local mean surrounding this pixel. (Wang, page 376). The gain factor k may be changed to control the amount of contrast enhancement. If k is increased, then the contrast is increased. Furthermore, any portion of k, according to Polaroid, may be used as the constant to control the amount of contrast enhancement. For example, k may be set equal to $1 + C$, where C provides the constant used for control. In Equation (5-3), Wang also teaches that g_{min} is applied to the value of $[g_{max}/g_{min}]$ raised to a power of $P(g(x,y))$. According to Polaroid, either of the values of $P(g(x,y))$ or g_{max} may be expressed as some number plus C, where C provides the constant used for control. Therefore, on Polaroid's theories, Wang teaches a number that may be increased to increase the amount of contrast enhancement.

Assessment of Claim 1

108. Applying Polaroid's proposed claim constructions and its infringement theories, I believe as discussed below that claim 1 of the '381 patent is anticipated by any one of the Gonzalez algorithm, Wang and Okada and that this claim is also obvious by any one of the Gonzalez algorithm, Wang or Okada in combination with any one of Gonzalez, Richard, Lee, Narendra, Sabri, Rangayyan and Chen.[9]

109. Independent claim 1 consists of a preamble and two means-plus-function claim elements: a means for averaging; and a means for selecting and transforming.

110. The preamble of claim 1 reads as follows:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

111. As described in my initial report, each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches this preamble in accordance with Polaroid's claim construction. (HP's Expert Report on Invalidity, paragraphs 205-216).

<u>…means for averaging….</u>

112. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

113. My understanding of Polaroid's position on the claim construction of this claim element has been stated in paragraphs 218-222 of HP's Expert Report on Invalidity. I understand Polaroid's position with respect to this claim element to be that the "means for

averaging" is a structure that performs a low-pass filtering or block averaging function on a plurality of pixels to produce an intermediate value corresponding to the values of those pixels, or its equivalent.

114. As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). Polaroid confirms that this is well-known by citing Gonzalez and Woods, Digital Image Processing, 2nd edition, in its Expert Report. Polaroid cites the 2001 edition of Gonzalez and Woods instead of the 1977 and 1987 editions of Gonzalez and Woods. However, these earlier editions of Gonzalez, as stated in HP's Expert Report on Invalidity, confirm that these techniques were well-known in the art long before the '381 patent was filed.

115. As described in my initial report, each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches averaging in accordance with Polaroid's claim construction. (HP's Expert Report on Invalidity, paragraphs 219-230).

<u>...means for selecting and transforming....</u>

116. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer

> function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

117. As previously stated in my initial report, I understand Polaroid's contention to be that the "means for selecting and transforming" is any algorithm that modifies a transformation function, such as ($Y_{MAX}(Y_{IN}/Y_{MAX})$) using a power, γ, that includes the result of a ratio of a calculated intermediate value (A_v) divided by any value within the dynamic range (M). (HP's Expert Report on Invalidity, paragraphs 232-234).

118. According to Polaroid any differences in the exponent of transfer functions are insubstantial. (Polaroid Expert Report, page 32). Polaroid asserts that the gamma in any exponent performs the same function for the transformation - selection of a transformation curve. as in the claimed invention (Id.). Thus, any exponent may select a transformation curve and satisfy this claim element.

119. Furthermore, as contended by Polaroid, any number may be expressed as a ratio of the average over any value within the dynamic range. The exponent is a number and thus may be expressed as a ratio to teach the exponent portion of the claimed algorithm as construed by Polaroid.

120. With the combination of any exponent satisfying this limitation and any number in the exponent expressable as a ratio, the structure disclosed in the '381 patent is the generic structure of any standard gamma transfer function, $Y=X^{\gamma}$. Furthermore, because the ratio of the average over any value in the dynamic range can be generated by the algebraic manipulation and the inclusion of a "scalar constant" (or variable), the exponent of such a transfer can be any gamma, γ. Based on Polaroid's own theories, the structure disclosed by the '381 patent (and claimed in Claims 1-3) is clearly present in the prior art.

121. Gamma transfer functions were well-known in the art long before the filing of the '381 patent. Okada also teaches gamma transfer functions (Okada, col. 2, 29-45; Fig. 5), Wang further teaches gamma transfer functions (Wang, page 373). Gonzalez and the Gonzalez algorithm, likewise, teach gamma transfer functions.[10] (Gonzalez, Appendix A; page 57).

122. Each of the references of the Gonzalez algorithm and Wang teaches transformation of an input signal by a transfer function comprising a power-law function and, according to Polaroid's theories, has an exponent that may be expressed as a ratio of the calculated intermediate value over a value within the range of values.

123. The Gonzalez algorithm transforms an input pixel, *I*, into an output pixel value *FLEV* as follows:

$$FLEV = FH * \mathrm{EXP}(SS*(GN-I)) + 0.5 \qquad \text{(Gonzalez, p. 454).}$$

In the above computer instructions, the transfer function includes a power-law function. The computer instruction EXP instructs a computer to use the value of *(SS*GN-I))* as an exponent. The value *SS* is computed as follows:

$$SS = (-1/GN) * \mathrm{ALOG}\ (FH/T) \qquad \text{(Id.)}$$

GN represents the maximum value of dynamic range of the intended output device. The value produced by the function SS is an exponent in the function FLEV to select the transformation curve. In accordance with Polaroid, any value in the exponent, in this case *(SS*(GN-I)),* may be expressed as a combination of other numbers in the form of a ratio, such as *Av/M*. In the variable SS, the quantity *FH/T* may be expressed in terms of a ratio, including an average, a scaling factor *D* and a value within the dynamic range, *M*:

$$\text{Let } FH/T \doteq D \times Av/M \text{ where } D = FH \times M/(T \times Av)$$

Therefore, the transfer function SS becomes:

[10] Other references also teach gamma functions, e.g., see U.S. Patent No. 4,751,566 to Pilot.

SS=(-1/GN) * ALOG (D × Av/M)

The ratio *Av /M* is a ratio comparable to the ratio (*Av/M*) in the '381 patent. The value *Av* is the average value of the pixels surrounding the pixel being processed. The value *M* may be set to any value in the dynamic range. Therefore, applying Polaroid's theories, the Gonzalez algorithm teaches transforming an input signal using a power-law transfer function where the transfer function is further selected as a ratio of the calculated intermediate value over a value in the range of values. On this additional basis, I confirm that the Gonzalez algorithm teaches this claim element.

124. Applying Polaroid's theories, Wang also teaches transforming an input signal using a power-law transfer function where the transfer function is further selected as a ratio of the calculated intermediate value over a value in the range of values. Wang describes the following power-law transformations in Equation (5-3):

$$g'(x, y) = g_{\min}\left[\frac{g_{\max}}{g_{\min}}\right]^{P(g(x, y))}$$

(Wang, page 373).

The value $g(x,y)$ is the input value which is transformed by the power-law function of $[g_{max}/g_{min}]^{P(g(x,y))}$ to produce the enhanced pixel value $g'(x,y)$. $P(g(x,y))$ is a value of a function applied to the pixel value at (x,y), in this example, the cumulative distribution function referred to as the CDF. The CDF is the integral of the probability density function (PDF) up to the value specified. This means that the CDF is given by the ratio defined as [total number of all pixels in the given image having the grayscale value up to and including $g(x,y)$] divided by [the total number of pixels in the given image]. (Id.) So, we have a power-law function that includes an exponent raised to the power of the ratio produced by this CDF. Although the CDF already produces a ratio of an calculated intermediate value over a value within a range of values, this

ratio is also a number than may be expressed as a combination of other numbers in accordance with Polaroid's expert report. The number $P(g(x,y))$ may be expressed in terms of a ratio of a value Av to a value within the dynamic range, M, along with a scaling factor D:

Let $P(g(x,y)) = Av/M * D$ where D is adjusted to maintain the original value of $P(g(x,y))$. For example, D may be set to $M/Av * P(g(x,y))$. Then, the transfer function becomes:

$$g'(x, y) = g_{\min} \left[\frac{g_{\max}}{g_{\min}} \right]^{Av/M * D}$$

Therefore, applying Polaroid's theories, Wang teaches transforming an input signal using a power-law transfer function where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values.

125. Furthermore, there is an additional basis for concluding that Wang teaches this claim element. Using Polaroid's theories, the formula of Wang may be algebraically manipulated to the formula $\gamma = (1 + C)^{(Av/M-1)}$ in the '381 patent as follows: g_{max} is greater than g_{min}. Therefore, we can let $g_{max} = g_{min} + k$, where k is a positive quantity, defined as $k = g_{max} - g_{min}$. Then, we have

$$g_{max} / g_{min} = (g_{min} + k) / g_{min} = 1 + k/g_{min} = 1 + C, \text{ where } C = k/g_{min}.$$

Furthermore, the power $P(g(x,y))$ in Wang's formula is mathematically defined as the ratio $P(g(x,y)) = N_{g(x,y)} / N_P$, where $N_{g(x,y)}$ is the number of pixels in the image with the grayscale value up to and including the value of $g(x,y)$, and N_P is the total number of pixels in the image. This is the mathematical definition of the CDF. Now, $N_{g(x,y)}$ must be less than or equal to N_P. Let us write $N_{g(x,y)} = N_P - N_r$, where N_r is the number of pixels in the image with grayscale value greater than that of $g(x,y)$. So, $N_r = N_P - N_{g(x,y)}$. Then, we have

$$P(g(x,y)) = N_{g(x,y)} / N_P = (N_P - N_r) / N_P = 1 - N_r / N_P = -(N_r / N_P - 1) = -(A_v/M - 1).$$

Here, we are letting $A_v = N_r$ and $M = N_P$. Both of these values are within the range of allowed values, and N_r is an intermediate calculated value. With the conversion of g_{max} / g_{min} to $1 + C$ and $P(g(x,y))$ to $(A_v/M - 1)$, the transformation equation becomes $g'(x,y) = g_{min}$ times

$$(1+C)^{(Av/M - 1)}$$

The above equation is comparable to that of the '381 patent. Therefore, again applying Polaroid's theories, Wang teaches transforming an input signal using a power-law transfer function where the transfer function is further selected as a ratio of the average value over a value in the dynamic range.

126. For the reasons stated above and those expressed in my initial report, I find that, in view of Polaroid's construction and Polaroid's theories on such construction, each and every element of claim 1[11] can be found in any one of the Gonzalez algorithm, Wang and Okada, and I am, therefore, of the opinion that claim 1 is invalid, as that concept has been explained to me.

127. Furthermore, as I have described above, each of Richard, Lee, Sabri, Rangayyan, Chen and Narendra describes image processing systems that use transform functions to transform an input pixel value and that use block averagers (the "means for averaging").

128. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Gonzalez is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Gonzalez

[11] I believe that claim 1 is also anticipated by Okada as described above.

reference and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Gonzalez in combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Gonzalez in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Gonzalez in combination with Okada.

129. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Richard is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Richard reference and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Richard in combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Richard in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Richard in combination with Okada.

130. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Lee is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Lee reference and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim

1 is obvious, as that term has been explained to me, in view of Lee in combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Lee in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Lee in combination with Okada.

131. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Sabri is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Sabri reference and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Sabri in combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Sabri in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Sabri in combination with Okada.

132. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Chen is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Chen reference and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of the Chen reference in

combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Chen in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Chen in combination with Okada.

133. It is my opinion that combining any one of the "means for selecting and transforming" of the Gonzalez algorithm, Wang or Okada with the image processing systems and methods described by Narendra is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Narendra and each of the Gonzalez algorithm, Wang or Okada references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Narendra in combination with the Gonzalez algorithm. I am also of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Narendra in combination with Wang. I am further of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Narendra in combination with Okada.

Assessment of Claim 2

134. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

135. Claim 2, recites a method having all the elements of claim 1 and including the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light and when a calculated intermediate value indicates high light condition. Such functions are suggested by any one of Gonzalez, Rangayyan, Richard, Lee, Narendra or Wang as described in my initial report or as further taught by Wang and Okada[12] as described above. (HP's Expert Report On Invalidity, paragraphs 245-251).

Assessment of Claim 3

136. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.

137. Under Polaroid's proposed claim construction, this claim recites a system having all the elements of claim 1 and claim 2, and the element that the transfer function is selected as a function of a chosen number, where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function.

138. Under Polaroid's theories in its Expert Report explained above, any number in a transfer function may include another number or constant chosen to control the amount of contrast enhancement applied to an incoming pixel value. (Polaroid Expert Report, page 51). According to Polaroid, a number of the transformation algorithm may be equated to the constant of C in the equation $(1 + C)$ of the '381 patent's algorithm. (Id.).

[12] Also as taught by Iida as described in this report.

139. Polaroid's theory provides an additional basis for the teaching of this claim element by the prior art. As explained above in connection with claim 9 under Polaroid's construction, each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, and Wang contains, and thus teaches, a number that may be increased to increase the amount of contrast enhancement that is performed in areas of the image where higher contrast is to be provided by the transfer function.

V. THE IIDA REFERENCE: ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION IN LIGHT OF POLAROID'S INFRINGEMENT CONTENTIONS AND CLAIM CONSTRUCTION.

140. In light of Polaroid's infringement theories asserted in its Expert Report, I considered whether U.S. Patent No. 4,394,688 (1983) to Iida et al. ("Iida") teaches the claimed invention of the '381 patent. It is my opinion that it does, and that, therefore, Claims 1-3 and 7-8 of the '381 patent are, in light of Polaroid's infringement theories, anticipated by Iida. Below, I detail my analysis of Iida with respect to those claims.

B. Iida Teaches Claim 7

141. In light of Polaroid's proposed claim constructions and its infringement theories, it is my opinion that claim 7 of the '381 patent is anticipated by Iida as follows:

<u>A method for continuously enhancing . . . .</u>

142. The Iida reference teaches an algorithm that performs transformation on a pixel-by-pixel basis. Iida teaches transforming each input pixel by using the formula $y=x^{\gamma}$. Iida, col. 1, lines 12-22). The value y is the output pixel transformed from the value of the input pixel x. This formula is applied to each input pixel value of the image, one at a time, to transform the

image into an enhanced image. (Iida, col .1, lines 12-22, the Figure; col. 3 line 38 to col. 4, line 8).

143. Consistent with my analysis of the other references to this preamble in my initial report, Iida teaches the preamble as construed by Polaroid:[13] successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits. Iida teaches methods for enhancing digital image data. (Iida, col. 1, lines 6-11). The processor receives a series of signals of a video image and converts the signals into digital image data. (Iida, col. 2, lines 45-55). As the video data are converted to digital data from an analog signal, the digital data are represented as numbers expressed as a certain number of bits. The certain number of bits is determined by the number of bits supported by the analog-to-digital converter of Iida. The digital data contain luminance values for each pixel. Iida teaches that the digital image is transformed into a new image by performing a transformation of the digital data. (Iida, col. 2, lines 45-65). In the case of the analog-to-digital converter being an 8-bit system, the video signal is converted to digital data or pixel values having a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Iida, therefore, teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.

<u>...averaging the electronic information signals....</u>

144. Iida teaches computing an average luminance value for a pixel taking into account the pixels surrounding the pixel to be averaged. Iida describes a processor that performs various

known image processing functions such as averaging. (Iida, col. 3, 57-62). An average, by its definition, takes into account multiple values. The averaging of Iida takes into account multiple values or pixel values of the digital data transmitted via the processor. (Id.). These multiple pixel values used for the average include values preceding or following the pixel value being processed (pixel values surrounding the pixel value being processed). (Id.) Thus, these pixel values surround the pixel value being processed. Therefore, Iida teaches calculating an intermediate value, that is, an average, for a selected group of pixels that provides pixel information.

...selecting one of a plurality of different transfer functions....

145. Iida teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Iida is an average of pixel values. Iida describes a processor that performs averaging on multiple pixel values of the digital data received by the processor. (Iida, col. 3, 57-62). Iida selects one of a plurality of different gamma correction values based on the average and the pixel being processed. (Id., col. 3, lines 1-7; col. 4 line 67 to col. 5, line 11). The multiplexer of Iida receives both the input signal – pixel value being processed – from the analog-to-digital converter (Iida, Fig. 1, element 19) and an average calculated by the processor (Iida, Fig. 1, element 23). The pixel data received by the multiplexer are modified by one of the selected gamma-correction values. The selected transfer function, in this case, relies on both the average and the input pixel being processed. Therefore, Iida teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Iida is an average of pixel values.

[13] HP's Expert Report on Invalidity, paragraphs 136-148.

...transforming the electronic information signal...

146. Iida teaches transforming an input signal based on an equation having a number that may be manipulated into a ratio of the intermediate calculated value over any value within a range of values. Iida teaches transformation of an input signal using the gamma function X^{γ}. (Iida, col. 1, lines 5-35). The value of gamma γ is a fractional value from 0.1 or lower to 3.0 or higher (col. 2, line 37). Iida also teaches that the transformation may be applied to a calculated intermediate value, such as an average. (Iida, col. 3, line 54 to col. 4, line 10). Under Polaroid's theory, a number, such as gamma γ may be expressed as a combination of other numbers. For example, the number for γ may be expressed as the ratio of the intermediate calculated value – the average - over 255 multiplied by D to maintain the original value of γ as follows: First, we start with the gamma power law function:

X^{γ} where γ is a number based on the average pixel value.

Then, we may express γ as a combination of other numbers by setting γ equal to a ratio of an average Av over a value M within the dynamic range.

$$X^{(Av/M)}$$

The value M may be set to a value within the dynamic range As average Av is also used as an input to the transfer function to produce gamma, it is available as a numerator. Further, the ratio A_v/M in the exponent is multiplied by the scaling factor D:

$$X^{(Av/M)\times D}$$

D is adjusted to a value to maintain the original value of the gamma. With M as a denominator and A_v as a numerator, the gamma of the transfer function of Iida may be expressed as the ratio of $\gamma = D \times A_v/M$. Therefore, Iida teaches transforming an input signal based on an equation

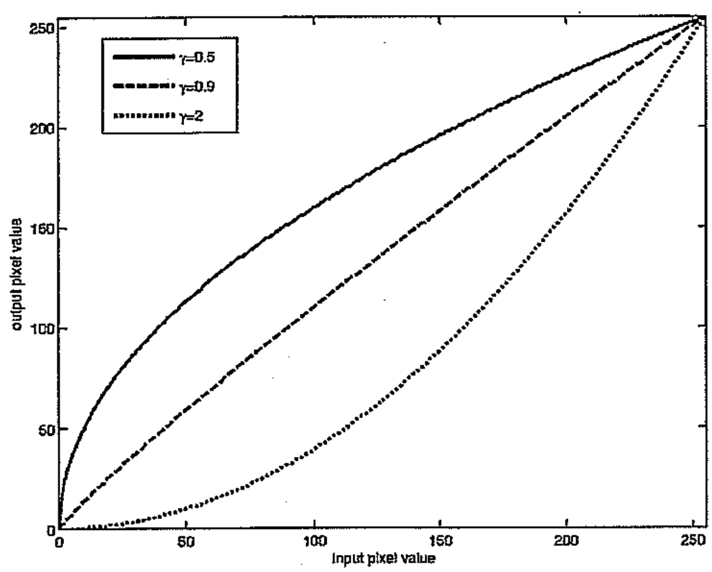
having a number that may be manipulated into a ratio of the intermediate calculated value over any value within a range of values.

147. For the reasons stated above, I find that, in view of Polaroid's construction and Polaroid's theories on such construction, each and every element of claim 7 can be found in Iida, and that, therefore, claim 7 is anticipated, as that concept has been explained to me, by the Iida reference.

Iida Teaches Claim 8

...higher contrast...to signals having lowest scene light intensity levels... and... having highest scene light intensity levels

148. Iida teaches an algorithm that selects a transfer function that produces data illustrating higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition, and hence teaches this claim element. The algorithm of Iida produces the following result.



In accordance with the above gamma curve, the darker pixels (those input pixel values in the range 0 – 100) receive a higher contrast enhancement with gamma of 0.5 than when gamma is

set to 0.9. Likewise, the lighter pixels (those input pixel values in the range 150 – 255) receive a higher contrast enhancement with gamma of 2 than when gamma is set to 0.9. Therefore, Iida teaches an algorithm that selects a transfer function that produces data illustrating higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition, and hence teaches this claim element as interpreted by Polaroid.

Iida Teaches Claim 9

149. As explained above in connection with claim 9 under Polaroid's construction, each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, and Wang contains, and thus teaches, a number that may be increased to increase the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function. I believe it would be an obvious extension to Iida to use any of the numbers that increase contrast as described above in view of any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra or Wang. As stated in my initial report, gain factors are well-known in the art, see, e.g., Gonzalez, Richard, Lee, Sabri, Narendra and Wang. (HP's Expert Report On Invalidity, paragraphs 311-312). As each of the references is directed to systems and methods of contrast enhancement, I also believe it would be an obvious extension to Iida to use any one of the gain factors taught by Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra or Wang.

Iida Teaches Claim 1

150. In light of Polaroid's proposed claim constructions and its infringement theories, I believe that claim 1 of the '381 patent is anticipated by Iida as follows:

<u>A system for continuously enhancing . . . .</u>

151. Iida teaches a system for enhancing digital image data. (Iida, col. 1, lines 6-11). The Iida system receives a series of signals of a video image and converts the signals into digital image data. (Iida, col. 2, lines 45-55). As the video data are converted from an analog signal to digital data, the digital data are represented as numbers expressed as a certain number of bits. The certain number of bits will be determined by the number of bits supported by the analog-to-digital converter of Iida. The digital data contain luminance values for each pixel. Iida teaches that the digital image is transformed into a new image by performing a transformation of the digital data. (Iida, col. 2, lines 45-65). In the case of the analog-to-digital converter being an 8-bit system, the video signal is converted to digital data or pixel values having a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Iida teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

<u>. . .means for averaging. . . .</u>

152. As described above in connection with the averaging step of claim 7, I explain that Iida teaches calculating an intermediate value, that is, an average, for a selected group of pixels that provides pixel information. Polaroid makes it clear that it believes any algorithm that

may be implemented in software may form a corresponding system in hardwired circuitry. (Polaroid's Expert Report, page 45). The Iida reference illustrates a hardware- and software-based system. The averaging done by Iida may be implemented in software as Polaroid contends. Thus, the system of Iida teaches this claim element as well.

<u>…means for selecting and transforming….</u>

153. As described above in connection with the transforming step of claim 7, I explain that Iida teaches transforming an input signal using a power-law transfer function where the transfer function is further selected as a ratio of the calculated intermediate value over a value in the range of values. The system of Iida may implement in software a corresponding algorithm in hardwired circuitry. (Polaroid's Expert Report, page 45). The selecting and transforming done by Iida may be implemented in software as Polaroid contends. Thus, the system of Iida teaches this claim element.

Iida Teaches Claim 2

154. As previously explained above for corresponding claim 8, Iida describes methods that lead to higher contrast under the conditions defined by this claim. Therefore, the system of Iida also teaches this claim element.

Iida Teaches Claim 3

155. As previously explained above for corresponding claim 9, Iida teaches methods that have a determined constant as defined by this claim. Therefore, the system of Iida also teaches this claim element.

VI. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION USING THE CLAIM CONSTRUCTIONS PROPOSED BY HP

156. In view of Polaroid's Theories advanced in its Expert Report, I provide further analysis below with regard to the invalidity of claims 1-3 and 7-9 respectively.[14]

B. Assessment of Claim 7

157. Again, I first assess claim 7, which is a method claim with a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

A method for continuously enhancing....

158. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

159. My understanding of HP's construction of this claim element has been stated in paragraphs 261-262 of HP's Expert Report on Invalidity. In HP's claim construction, the preamble is construed, in part, as "an uninterrupted stream of received luminance image data defining an original image to be recorded". (HP's Expert Report on Invalidity, paragraphs 261-262).

160. Polaroid contends that the alleged HP products perform the functionality of the preamble by transforming each pixel in an image without pausing. In view of Polaroid's

[14] In my initial report, I concluded that claims 7-9 are an obvious extension of Richard and the claim 7 is an obvious extension of Sabri. In this report, I conclude that claims 7-9 are taught under Polaroid's theories by each of the Gonzalez algorithm, Gonzalez, Richard, Lee, Narendra, Sabri, Rangayyan, Chen, Wang, Okada and Iida.

characterization of this preamble,[15] a software-based algorithm performing contrast enhancement on a pixel-by-pixel basis for each pixel for the entire image teaches this claim element. Unless an error condition or exception event occurs, there is no reason for the contrast enhancement algorithm not to continue transforming, without pausing, each and every pixel of the image if enhancing the entire image.

161. As explained above in connection with my assessment of the preamble of claim 7 under Polaroid's construction, each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches pixel operators or pixel-by-pixel transformations. All of these algorithms provide an enhanced image by transforming each pixel, one at a time, until all the pixels in the image are transformed. Therefore, each of these references teaches this claim element in view of Polaroid's characterization of the HP's claim construction.[16]

...averaging the electronic information signals...

162. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

163. My understanding of HP's construction of this claim element has been stated in paragraphs 267-268 of HP's Expert Report on Invalidity. As construed by HP, this step reads as calculating the arithmetic mean for a selected group of pixels.

164. In connection with my analysis above of claim 7 using Polaroid's construction, I confirm that averaging electronic information signals, for example, by using low-pass filtering

[15] I forego commenting on whether or not Polaroid's contention meets HP's proposed claim construction.
[16] If accepted by the Court.

and block averaging techniques, was well-known and disclosed by at least each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

selecting one of a plurality of different transfer functions…..

165. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

166. My understanding of HP's construction of this claim element has been stated in paragraph 270 of HP's Expert Report on Invalidity. In HP's claim construction, this element is construed, in part, as: "where each input pixel is part of only one average". (HP's Expert Report on Invalidity, paragraph 270).

167. As stated above, Polaroid contends that any repeating block averager or low-pass filter is substantially the same as a non-repeating block averager and for purposes of this assessment, I will treat any repeating block averager as providing the non-repeating block averager of HP's claim construction. As stated in my initial report, each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teach block-averagers, such as repeating block averagers. Therefore, in accordance with Polaroid's assertions, these references also teach block averagers, and thus, teach this claim element. (Id).

168. As explained above in connection with my assessment of this claim element under Polaroid's construction, each of the references of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches selecting a transform function based on the input pixel value

and an average value of a group of pixels including the input pixel. As described above n connection with my assessment of corresponding average element of claim 1 under Polaroid's construction, the Gonzalez algorithm can be manipulated according to Polaroid's theories to have an average. fore, each of the references of Gonzalez, the Gonzalez algorithm, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches this claim element in view of Polaroid's characterization of the HP's claim construction.

<u>....transforming the electronic information signal....</u>

169. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

170. My understanding of HP's construction of this claim element has been stated in paragraph 274 of HP's Expert Report on Invalidity. As construed by HP, this last step performs altering an input signal using the pixel value itself and an arithmetic mean of the value of a group of pixels associated with the pixel, and is further based on the result of dividing the arithmetic mean associated with the pixel group by an integer value within a range of values that represent the dynamic range.

171. Based on Polaroid's theories in its Expert Report, a ratio may be constructed from a number. A denominator in a ratio or a divisor in a division operator does not need to exist in the transfer function. A number in the equation of the transfer function may be manipulated into a ratio by dividing the average by an integer value, *M,* within the dynamic range. Then, the value *M* is adjusted by a scaling factor *D* to maintain the original value of the number. The value

of *M* may selected to be any point in the dynamic range for which the least contrast enhancement is desired.

172. As explained above with respect to this claim element for Polaroid's construction, such a ratio and this claim element are taught by each of Gonzalez, Lee, Rangayyan, Chen, Narendra, and Wang.[17] Each of these references, in view of Polaroid's theories, can be made to have the ratio in accordance with HP's construction.

173. For the reasons stated above in combination with those expressed in my initial report I find that, in view of Polaroid's construction and Polaroid's theories on such construction, each and every element of claim 7 can be found in any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, Wang and Okada[18], and that, therefore, claim 7 is anticipated, as that concept has been explained to me, by each one of those references.

C. Assessment of Claim 8

174. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

175. As stated in HP's Expert Report on Invalidity, paragraph 280, claim 8 requires a method having all the elements of claim 7 and the additional element that the transfer function is selected to provide higher contrast to pixels when the calculated arithmetic mean indicates a low light or high light condition.

[17] Richard and Sabri also teach this claim element as explained in my initial report (see HP's Expert Report on Invalidity, paragraphs 276- 277).

176. As explained above in connection with my assessment of this claim element under Polaroid's claim construction, Okada produces resulting phenomenon of higher contrast under the conditions defined by this claim. The difference between Polaroid's and HP's possible claim construction for this claim is the use of average in HP's construction instead of an intermediate calculated value in Polaroid's construction. Okada uses an average to perform his transformations. Thus, Okada also teaches this claim element under HP's construction.

177. Furthermore, as discussed above in connection with this claim element under Polaroid's claim construction and in my initial report, each of the references of Gonzalez, Rangayyan, Richard, Lee, Narendra and Wang[19] teach or suggest this claim element.

D. Assessment of Claim 9

178. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

179. Under HP's claim construction, claim 9 recites a method having all the elements of claim 8 and claim 7, and the additional element that the transfer function is selected as a function of a control parameter, where increasing the control parameter increases the amount of contrast enhancement that is performed. (See Joint Claim Construction).

180. Under Polaroid's theories in its Expert Report explained above, any number in a transfer function may include a control parameter chosen to control the amount of contrast enhancement applied for an incoming pixel value. (Polaroid Expert Report, page 51). According to Polaroid, a number in the transformation algorithm may be equated to the control parameter of

[18] I also believe Okada anticipates these claims as described above.

C in the equation *(1 + C)* of the '381 patent's algorithm. (Id.). This theory of Polaroid provides an additional basis for teaching this claim element by the prior art.

181. As previously explained above for claim 9 under Polaroid's claim construction, each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang contains, and thus teaches, a number that may be increased to increase the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function.

E. Iida Reference Teaches Claims 7-9

182. As previously explained above, the Iida reference teaches each of claims 7-8 under Polaroid's claim construction and infringement theories. The same analysis applies under HP's construction. In light of Polaroid's infringement theories, I believe that claims 7-8 of the '381 patent are anticipated by Iida under HP's claim construction.

183. As previously explained above, the Iida reference in combination with any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Narendra, Sabri, Rangayyan, Chen, Wang or Okada teaches claim 9 under Polaroid's claim construction and infringement theories. The same analysis applies under HP's construction. In light of Polaroid's infringement theories, I believe that claim 9 of the '381 patent is an obvious extension of Iida under HP's claim construction.

F. Assessment of Claim 1

184. Independent claim 1 consists of a preamble and two means-plus-function claim elements: a means for averaging, and a means for selecting and transforming.

185. The preamble of claim 1 reads as follows:

[19] As well as Iida as described herein.

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

186. In its Expert Report, Polaroid provides the same opinion regarding the analysis and characterization of the preamble of claim 1 as it does for the preamble of claim 7. Thus, Polaroid does not make any distinction between these preambles.

187. Therefore, my assessment of this preamble in view of Polaroid's theories discussed in claim 7 above applies here as well. Each of the references of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang teaches this claim element.[20]

188. Even with the preamble of this claim being a system claim, Polaroid makes it clear that it believes any algorithm that may be implemented in software may form a corresponding system in hardwired circuitry. (Polaroid's Expert Report, page 45). As each of the references of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang contains algorithms that may be based in software or hardware in accordance with Polaroid, each of these references provides a system with respect to this claim.

<u>...means for averaging...</u>

189. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

190. As HP's construction requires a buffer, Polaroid advances the theory that a data structure in a software program implementing the algorithm teaches this buffer element.

(Polaroid's Expert Report, pages 41-42). A data structure is a way of storing data in a computer. The data structure is defined by one or more computer executable instructions in a software program. Whether or not a data structure is a buffer under HP's construction, for the purpose of this assessment, if the algorithm may be implemented in software it also will have a data structure (i.e., a buffer in accordance with Polaroid).

191. In connection with my analysis above of claim 7 using Polaroid's construction and as stated in my initial report, I discussed that averaging electronic information signals, for example, by using low-pass filtering and block averaging techniques are well-known and are taught by at least each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

192. Since any of the algorithms of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang may be implemented in software, each of these references teaches a buffer in the form of a data structure for providing the average value.

<u>...means for selecting and transforming...</u>

193. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

194. In its Expert Report, Polaroid contends that HP's identified structure of FIG. 4 corresponding to the following function:

$$Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}, \text{ where } \gamma = (1+C)^{(Av/M-1)}$$

is the same as an algorithm implemented in software that selects a transfer function based on the incoming pixel value and the result of dividing the average value by any value within an upper portion of the dynamic range of the signal. (Polaroid Expert Report, pages 43-44).

195. Polaroid's theories provide a basis for concluding that each of Gonzalez, Richard, Lee, Rangayyan, Chen, Narendra, and Wang teaches a software-based algorithm that selects a transfer function based on the result of dividing the average value by any value within an upper portion of the dynamic range of the signal.

196. As previously explained above in connection with my assessment of claim 7, each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang performs the step of altering an input signal using the pixel value itself and an arithmetic mean of the value of a group of pixels associated with the pixel, and is further based on the result of dividing the arithmetic mean associated with the pixel group by an integer value within a range of values that represent the dynamic range. Thus, each of these references teaches this claim element.

197. For the reasons stated above in combination with those expressed in my initial report, I find that, in view of Polaroid's construction and Polaroid's theories on such construction, each and every element of claim 1[21] can be found in any of one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang, and I am, therefore, of the opinion that claim 1 is invalid, as that concept has been explained to me.

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[21] I believe that claim 1 is also anticipated by Okada as described above.

198. Additionally, as explained in my assessment of claim 1 under Polaroid's construction, the image processing system of the Gonzalez algorithm teaches each and every element of claim 1. Under HP's construction of claim 1, the Gonzalez algorithm does not have an existing average value in the selected transfer function[22] - although such an average can be manipulated under Polaroid's theories. However, it is my opinion, that it would be obvious to combine the Gonzalez algorithm with any of one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, Wang and Okada references as follows.

199. As I described above, each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, Wang and Okada describes image processing systems that teach each of the elements of the claimed invention.

200. It is my opinion that combining any of the image processing system of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, Wang and Okada with the image processing system of the Gonzalez algorithm is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Gonzalez algorithm and each of the respective references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over the Gonzalez algorithm in combination with any one of the references of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, Wang and Okada.

G. Assessment of Claim 2

201. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the

[22] It has an intermediate calculated value, under Polaroid's construction, that is not explicitly an average.

> electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

202. Claim 2 recites a method having all the elements of claim 1 and including the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light and when a calculated intermediate value indicates a high light condition.

203. As discussed in my initial report and as well as with my above assessment of claim 2 under Polaroid's construction, Okada as well as the references of Rangayyan, Richard, Gonzalez, Lee, Narendra and Wang teach this claim element.[23]

H. Assessment of Claim 3

204. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.

205. Under HP's claim construction, claim 3 recites a system having all the elements of claim 1 and claim 2 and the additional element that the transfer function is selected as a function of a control parameter, where increasing the control parameter increases the amount of contrast enhancement that is performed. (See Joint Claim Construction).

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[23] Furthermore, Iida teaches this claim element as well as described in this report.

206. Under Polaroid's theories in its Expert Report explained above, any number in a transfer function may be modified to include a control parameter chosen to control the amount of contrast enhancement applied for an incoming pixel value. (Polaroid Expert Report, page 51). According to Polaroid, a number of the transformation algorithm may be equated to the control parameter of *C* in the equation *(1 + C)* of the '381 patent's algorithm. (Id.). This theory of Polaroid provides an additional basis for teaching this claim element by the prior art.

207. As previously explained above for claim 9 under both HP's and Polaroid's claim construction, each of the references of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra, and Wang contains, and thus teaches, a number that may be increased to increase the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function.

I. Iida Reference Teaches Claims 1-3

208. As previously explained above, the Iida reference teaches each of claims 1-3 under Polaroid's claim construction and infringement theories. The same analysis applies under HP's construction. In light of Polaroid's infringement theories, I believe that claims 1-3 of the '381 patent is anticipated by Iida under HP's claim construction.

VII. ASSESSMENT OF COMPLIANCE OF THE SPECIFICATION OF THE '381 PATENT WITH THE WRITTEN DESCRIPTION REQUIREMENT IN LIGHT OF POLAROID'S INFRINGEMENT CONTENTIONS AND CLAIM CONSTRUCTION

209. As I understand and as it has been explained to me, a patent application must comply with the written description requirement of 35 U.S.C. §112, first paragraph, which, in part, requires that the "specification shall contain a written description of the invention." As further explained to me, to satisfy the written description requirement, a patent specification

must describe the claimed invention in sufficient detail that one skilled in the art can reasonably conclude that the inventor(s) had possession of the claimed invention.

210. I have been asked to compare the scope of the claims in view of Polaroid's assertions on claim construction to the scope of the specification of the '381 patent to determine whether or not specification one skilled in the art would, upon reading the specification, reasonably conclude that the inventors had possession of the claimed invention as now claimed by Polaroid.

211. As detailed below, I do not believe that the '381 patent describes the claimed invention in sufficient detail that one skilled in the art can reasonably conclude that Polaroid had possession of an invention with the scope asserted by Polaroid in its Expert Report.

212. In view of Polaroid's claim construction and asserted theories, Polaroid contends that it was in possession of an invention covering systems and methods that: (i) employ algorithms that do not contain a ratio as written, because such algorithms can be reconstructed to contain a ratio and a "scaling variable", (ii) employ any transfer function which can be algebraically manipulated to include the algebraic phrase $(Av/M\text{-}1) * D$ after replacement of one or more values with a ratio and a "scaling variable.", and (iii) employ transfer functions with any kind of exponent because any differences in exponents of transfer functions are insubstantial.

213. The specification of the '381 patent, is focused on the determination of gamma being made as a function of the average value and a value M in the dynamic range where the least image enhancement is desired: ('381 patent, col. 4, lines 26-50). One ordinary skilled in the art would find this to be the invention which the specification is intending to describe. Most of the written material of the specification is dedicated to the description of: (i) determining the average ('381 patent, col. 3, line 52 to col. 4 line 25) and (ii) using the determined average in the

gamma transfer function $\gamma = (1 + C)(Av/M - 1)$. ('381 patent, col. 4, line 25 to col. 6, line 42). In the remaining portion of the specification, the '381 patent describes the only alternative embodiment of this gamma function, which is simply rewritten in the form of a logarithm relationship: $\log \gamma = (Av/M - 1)[\log(1 + C)]$. ('381 patent, col. 6, line 42 to col. 7, line 54).

214. The only variations to components of the gamma transfer function, $\gamma = (1 + C)(Av/M - 1)$, described by the '381 patent are changes to the values of *C* and *M*. ('381 patent, col. 4, lines 26-67).

215. Nowhere in the '381 patent does it describe how to construct the ratio of Av/M from other numbers when this ratio does not exist in the transfer function.

216. Nowhere in the '381 patent does it describe how to algebraically manipulate equations of transfer functions to provide this ratio when the ratio does not exist in the transfer function.

217. Nowhere in the '381 patent does it describe that any differences in exponents of transfer functions are insubstantial.

218. Although the '381 patent indicates that other embodiments of the invention will be obvious to those skilled in the art ('381 patent, col. 7, lines 55-59), one of ordinary skill in the art would not deem the other contrast enhancement techniques that would fall within the scope of the claims alleged by Polaroid to be other embodiments of the invention as described in the specification.

219. Specifically, one of ordinary skilled in the art would not understand from reading the specification that the '381 patent that the invention included and/or the application intended to cover systems or methods in which: (i) algorithms that do not contain a ratio can be reconstructed to contain a ratio using a "scaling variable", (ii) transfer functions without the ratio

can be algebraically manipulated to include the algebraic phrase *(Av/M-1) * D* after replacement of one or more values with a ratio and a "scaling variable", and (iii) differences in the exponents of transfer functions are insubstantial.

220. Absent any suggestion by the '381 patent itself, one of ordinary skill in the art would not derive from the specification that the invention covers the broader range of gamma transfer functions in which a non-existing ratio may be formed, in accordance with Polaroid's theories, by (i) changing any number into a ratio using a scaling function and (ii) algebraically modifying the equation to include the ratio.

221. Furthermore, the two embodiments of the invention described by the '381 patent, (i) $\gamma = (1 + C)(Av/M - 1)$ and (ii) $\log \gamma = (Av/M - 1)[\log(1 + C)]$ do not provide a sufficient representative number of variation and types of transfer functions that would lead one ordinarily skilled in the art to believe that Polaroid had possession of the invention with the more generic and broader scope they assert. In fact, the lack of variation between these two embodiments would lead one ordinarily skilled in the art to believe that (i) the algebraic form of the equation having the ratio is an identifying characteristic of the invention and (ii) differences in the exponent of the transfer function would not be considered insubstantial.

222. For at least the above reasons, I do not believe that the '381 patent describes the claimed invention in sufficient detail that one skilled in the art can reasonably conclude that Polaroid had possession of the invention with the scope of claims as asserted by Polaroid . Therefore, I conclude that the specification of the '381 patent fails to the meet the written description requirement as it has been explained to me.

VIII. CONCLUSION

It is my opinion that the subject matters of claims 1-3 and 7-9 of the '381 patent lack novelty or are otherwise obvious in view of my assessment in both my initial report and this supplemental report.

Rangaraj Rangayyan, Ph.D.

EXHIBIT A

1. The Expert Report of Dr. Peggy Agouris regarding U.S. Patent No. 4,829,381.
2. U.S. Patent No. 4,394,688.
3. U.S. Patent No. 4,751,566.

EXHIBIT 3

REDACTED

EXHIBIT 4

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION, Plaintiff, v. HEWLETT-PACKARD COMPANY, Defendant.	C.A. No. 06-783 (SLR)

EXPERT REPORT OF DR. RANGARAJ RANGAYYAN

I, Dr. Rangaraj Rangayyan, submit this report on behalf of the defendant Hewlett-Packard Company ("HP").

I. INTRODUCTION

1. I am a full professor in the Department of Electrical and Computer Engineering at the University of Calgary, which is in Calgary, Alberta, Canada ("UofC"). I am also an adjunct professor in the Departments of Surgery and Radiology at UofC. I have been a professor in the Department of Electrical and Computer Engineering at UofC since 1984.

2. I have been elected as a Fellow of the following professional organizations: Institute of Electrical and Electronics Engineers (2001), Engineering Institute of Canada (2002), American Institute for Medical and Biological Engineering (2003), the International Society for Optical Engineering (2003), Society for Imaging Informatics in Medicine (2007) and the Canadian Medical and Biological Engineering Society (2007). I am also a registered Professional Engineer in the Province of Alberta, Canada.

3. I hold a Bachelor of Engineering (B.E.) in Electronics and Communication from the University of Mysore, Mysore, India (1977). In 1980 I was awarded a Ph.D. degree in Electrical Engineering from the Indian Institute of Science, Bangalore, India. While a graduate student at the Indian Institute of Science, I began my studies and research on digital image processing. My Ph.D. dissertation focused on digital signal processing techniques for computerized analysis of biomedical signals, such as the electrocardiogram (ECG) and heart sounds.

4. Prior to joining the faculty at UofC in 1984, I was an assistant professor in the Department of Electrical Engineering at the University of Manitoba in Winnipeg, Canada ("UMan"). I was also a systems analyst in the Department of Pathology at UMan. While at UMan, I conducted research on adaptive contrast enhancement techniques for digital signal and image processing and on contrast enhancement of mammograms, which are X-ray images of the breast.

5. In 1982, as an assistant professor at UMan, I developed a new graduate-level course on digital image processing. When I moved to UofC in 1984, I established a course directed to the same subject matter at UofC. Collectively, I have taught a graduate-level course on digital image processing for the last twenty-five years.

6. I have supervised dozens of graduate and undergraduate students on thesis-oriented research work. Several of these projects were directed towards the development of image processing and contrast enhancement techniques.

7. I have given many lectures, research seminars, and tutorials on digital image processing, medical imaging and image analysis, biomedical signal analysis, and related topics. I have also collaborated with researchers at universities, institutes, and research organizations in

India, Canada, the United States, Brazil, Argentina, Uruguay, Chile, the United Kingdom, Russia, The Netherlands, Egypt, France, Spain, Italy, Romania, Malaysia, Singapore, Thailand, Japan, Hong Kong, and China.

8. Because of my expertise in image and signal processing, I have held, or currently hold, Visiting or Adjunct Professorships at: University of Liverpool, Liverpool, UK (2006-current); Tampere University of Technology, Tampere, Finland (1998, 1999, 2007); Universitatea Politehnica Bucureşti, Bucharest, Romania (1996, 1997, 1998); Universidade de São Paulo, São Paulo, Brasil (1994-95); Cleveland Clinic Foundation, Cleveland, Ohio, USA (1999); Indian Institute of Science, Bangalore, India (1988, 1994); Manipal Institute of Technology, Manipal, India (2006-current); Beijing University of Posts and Telecommunications, Beijing, China (2006-current); and École Nationale Supérieure des Télécommunications de Bretagne, Brest, France (1995, 1999).

9. I have authored over 300 journal papers and conference publications, most of which are directed to image processing, and many of which are directed specifically to contrast enhancement in digital images.

10. I am the author of the following university-level textbooks directed towards image and signal processing: "Biomedical Signal Analysis" (IEEE Press and Wiley, New York, NY, 2002); and "Biomedical Image Analysis" (CRC Press, Boca Raton, FL, 2005).

11. A full list of my research, publications, awards and recognitions are provided with my curriculum vitae, a copy of which is attached as Appendix A.

12. I have conducted research on, and developed, several algorithms for biomedical signal and image processing applications. One of the major applications on which I have worked is the analysis and contrast enhancement of mammograms for computer-aided diagnosis of breast

cancer. Methods that I developed for contrast enhancement in mammograms have allowed radiologists to differentiate more accurately between malignant and non-malignant disease of the breast, leading to earlier detection of breast cancer.

13. I have been asked to serve as an expert witness in this litigation. Prior to my engagement, I had never consulted to Choate, Hall & Stewart, LLP, Fish and Richardson P.C., or HP. I have not previously been retained as an expert witness in any litigation. I have been, and expect to be, compensated for these services at my customary consulting rate of $300.00 per hour. My compensation for these services is not contingent upon the outcome of this action.

14. I have been asked to review U.S. Patent No. 4,829, 381 ("the '381 patent") and assess the validity of the '381 patent.

15. In rendering my opinion, I have reviewed the documents and materials attached to or described in Exhibit B. In particular, I have read the '381 patent, its file history, the cited references and the prior art references identified in this report. I have also reviewed the claim constructions proposed by HP and by Polaroid.

16. I understand that fact discovery in this matter is closed. However, I have been told that some discovery material may not be available until after the date of this report. Therefore, I may supplement this report as necessary or appropriate in view of further discovery or other events, including any ruling by the Court that is pertinent to my analysis. In addition, if requested, I may supplement this report and/or testify at trial in response to evidence put forward, or expert testimony advanced, by Polaroid.

17. The objective of my investigation was to assess whether that which is claimed in the '381 patent was novel and not obvious, as those terms have been explained to me, in view of

the art that existed at the time the '381 patent was filed. I carried out this investigation personally.

18. It is my opinion that the invention claimed in the '381 patent is either not novel or is obvious, as those terms have been explained to me, in view of the art that existed at the time the '381 patent was filed.

19. I may use the exhibits to this report and any referenced documents and information to support testimony concerning the '381 patent, the state of the art of image processing and the subject matter of my investigation. In addition, I may use any diagrams, aids or other presentation materials to illustrate my analysis of the '381 patent or any other technology described in this report.

II. BACKGROUND

A. Digital Image Processing

20. At trial, I may be asked to testify about, and explain, the fundamentals of digital image processing. In brief, an image is a visual representation of a person, an object or a scene that is produced or displayed on a surface, such as paper. For example, a photograph produced by a camera provides a visual representation, or image of the scene which the camera captured. The photograph is considered a human-readable format of the image.

21. A digital version of the image, or digital image, is the image stored as numerical values in an electronic device, such as a computer. The numerical values are the computer-readable version of the human-readable image. For example, a photograph scanned into a computer is converted from its human-readable format of the photograph to a computer-readable digital format.

22. In computer-readable format, a digital image is made up of a fixed number of rows and columns. Each intersection point of the rows and columns is represented by a value.

Each value is a numerical representation of an element of the picture at that point. This picture element is often referred to as a "pixel." Thus, a digital image having 256 rows and 256 columns would be represented by a total of 256 x 256, or 65,536, pixels.

23. In a digital image the values for a pixel have a fixed range of values. The range is limited by the number of bits used to express each pixel value. The larger the number of bits used to store a value, the greater the number of different values that may be stored. Conversely, the smaller the number of bits used to store values, the smaller the number of different values that may be stored.

24. In a rudimentary example, each pixel might be represented by a one bit value. That is, each pixel would be represented by either a "1" or a "0." In this form, one of the pixel values indicates that the pixel is "on" and the other indicates that the pixel is "off." Using this system, a digital image may be represented as a collection of black pixels and white pixels.

25. Using more bits to represent each pixel allows a pixel in a black-and-white image to represent shades of gray. If each pixel value were represented by a 4-bit value, then each pixel could have one of a possible 16 values, for example, 16 shades of gray ranging from "white" to "black." This simple example illustrates the concept of "luminance," that is, the brightness of an image. In an image in which each pixel is one of 16 shades of gray (commonly referred to as a "grayscale image"), each pixel value represents the brightness, or luminance, of the image at that point. The tiny area of the image represented by a pixel may itself have a range of luminance values. A pixel, therefore, represents the average luminance for the area of the image to which it corresponds.

26. The concept of luminance is not restricted to grayscale images. In the example immediately above, each pixel value could represent 16 shades of another color ranging from

black to the other color. The difference between the maximum value that a pixel may have and the minimum value that a pixel may have is referred to as the "dynamic range." In the four-bit example, the color ranges from "0000" (very dark) to "1111" (very bright)," and the dynamic range is 0 (0000) to 15 (1111).

27. An inherent element of digital images is that pixels have a discrete number of brightness levels within the dynamic range. In the four-bit example, there are sixteen levels. However, images in the real world are not limited to an arbitrary number of brightness levels that are represented by a fixed number of bits in a digital image. For example, an outdoor scene may contain areas with bright sunlight and dark shadow and many different gradations in between (indeed, there are potentially an infinite number of brightness levels in the scene itself). The number of gradation levels may very well exceed the number of discrete brightness levels afforded by a digital system.

28. When a digital imaging device attempts to represent a real-world scene, it must do so using only values that exist within its dynamic range. If the actual number of degrees of brightness of the real-world scene is greater than the number of brightness levels the device can represent using its dynamic range (as is typically the case), the imaging device must attempt to represent the actual variations of the image within the values that are available to it. That is, there are only a limited number of values to assign to a pixel to try to account for the infinite number of brightness levels in the actual scene.

29. A digital image may be modified using digital image processing, which is the use of a device that "reads" an input image and, through a series of steps, produces an output image with desired properties. These steps may be referred to as routines, which collectively may be referred to as a process or a method. The process of changing the properties of a digital image

may be referred to as transformation. Changes to the size, resolution or color of an image are types of transformations.

30. Transformation of digital images via digital image processing may be used to improve the quality of the image. The transformation may include one or more enhancement functions, techniques or algorithms to process an image so that the resulting digital image is more suitable than the original image. A transformation changes the original pixel values of a digital image to different pixel values in the processed output image. A transformation function may be applied to one pixel at a time (i.e., on a pixel-by-pixel basis), or to groups of pixels. Many of these transformations are directed to dealing with the challenges of representing the wide dynamic range of brightness in a real-world scene using the fixed dynamic range available for a digital image.

31. One type of transformation that may be applied to a digital image is "contrast enhancement," which may also be referred to as "gamma correction" by those skilled in the art. Contrast enhancement attempts to increase the difference in appearance between adjacent pixels or groups of pixels in an image. This is accomplished by increasing the difference between the value of a single pixel and the value of pixels in an area adjacent to that pixel.

32. The amount by which an input pixel value is changed when transforming an image may be effected by a linear transformation function or nonlinear transformation function. A linear transformation function changes each input pixel value to a new output pixel value by the same factor for all the pixels that make up an image. That is, each output pixel value is directly proportional to the corresponding input pixel value. A nonlinear transformation function changes input pixel values to output pixel values by different factors at different points in the digital image. For example, when a nonlinear transformation function is used, a first input pixel

may be changed to an output pixel value by a factor of 0.5, whereas a second input pixel may be changed to an output pixel by a factor of 2.

33. Local area contrast enhancement may be performed by increasing the difference between a single pixel's value and the average value of pixels in an area adjacent to that pixel. The group of pixels in the area adjacent to the subject pixel is referred to as a neighborhood or window. The average value of the neighboring pixels may be determined by adding the values of a group of pixels in the neighborhood, or local area, of the subject pixel and dividing by the number of pixels in the neighboring area. A local contrast measure may be determined by taking the difference between the value of the subject pixel and the average value of the pixels in the local area. Local contrast enhancement may change the value of the subject pixel as compared to the average value of the pixels in the neighborhood of the pixel, so as to increase the difference in appearance between them.

B. State of the Art in Digital Image Processing Prior to the '381 Patent

34. Techniques for transforming digital images have been known for decades. For example, the Jet Propulsion Laboratory ("JPL") was assigned the task of improving the quality of transmitted images of Apollo 11 landing on the Moon in 1969. JPL conducted research and developed several transformation and contrast enhancement techniques to improve the quality of digital images.

35. During the 1970s and 1980s there was wide recognition of the desirability of improving digital output images so as to increase the contrast within areas of an image and thus make details in the image more visible to human observers. A variety of techniques were developed that addressed this problem. As will be apparent from the rest of this report, many of

these techniques include the same or similar components and many of the components of particular techniques were similar to the components of these image techniques.

36. When I developed my graduate-level course on digital image processing in 1982, I used three texts that specifically summarized a number of digital image processing techniques and which I discuss later in this report: (1) "Digital Image Processing", by Gonzalez R.C. and Wintz P., (Addison-Wesley, Reading, MA, 1977) ("Gonzalez"); (2) "Computer Image Processing and Recognition", by Hall E.L., (Academic, New York, NY, 1979) ("Hall"); and (3) "Digital Picture Processing", by Rosenfeld A. and Kak A., (Academic, San Diego, CA, Vol. 1-2, 1982) (Rosenfeld").

The Gonzalez and Hall Textbooks

37. The Gonzalez textbook was published in 1977. It includes many then well-known image enhancement techniques developed prior to 1977. (See Gonzalez, Chapters 3 and 4). The Hall textbook was published in 1979. It describes many then well-known image enhancement techniques developed prior to 1979. (See Hall, Chapters 3 and 4). Many of the techniques published in the Gonzalez textbook and the Hall textbook were taught to university students throughout the late 1970s and 1980s.

38. The Gonzalez textbook, in its Appendix A, includes a software algorithm that receives a digital image and prints it on a printer. The printer had a dynamic range from 0 to 31; that is, the line printer was capable of representing only 32 shades of gray. The algorithm in Gonzalez accepted images having a different dynamic range from that of the line printer. In such a situation, the input values of two adjacent pixels may be similar even though each pixel represented a part of the real-world image that was actually different. Therefore, the Gonzalez algorithm taught a technique for modifying the values of the pixels that made up the input image

so as to enhance the contrast between individual pixels and thus to improve the image generated by the printer.

39. The Hall textbook describes systems and methods for transforming pixel values that collectively define an image. (Hall, Section 3.2).

40. Hall described pixels as having values within a range of possible values determined by the number of bits used to represent each pixel value (Hall, Section 3.2.2 on quantization and Fig 3.1.3 illustrating images using different number of bits per pixel).

41. The Hall textbook taught, as early as 1979, that the contrast between a pixel and its surrounding area could be calculated by comparing the luminance value of the subject pixel to the average luminance value of the pixels in its immediate surrounding area. (See Hall, p. 27).

42. Hall dedicated an entire chapter to image enhancement. That chapter included a 27-page section describing multiple methods for performing contrast enhancement (Hall, pages 159-185).

43. Hall stated that "contrast generally refers to a difference in luminance or gray level values in some particular region of an image…." (Hall, p. 159).

44. Hall described measuring contrast as the ratio of the difference in luminance of an object, B_0, and the luminance of its immediate surround, B, to the luminance of the immediate surround, B.

$$C = (B_0 - B)/B$$

(Hall, p. 27).

45. Hall demonstrates that, as of 1979, it was well-known to use a neighborhood of pixels (e.g., a pixel and its eight immediate neighbors or, alternatively, a pixel's eight immediate

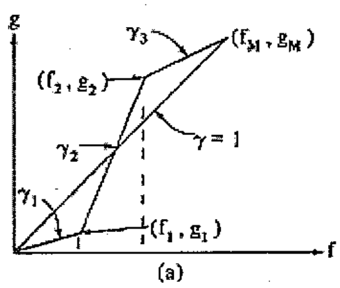
neighbors) to process digital images. (Hall. p. 205). Figure 4.32 on page 206 of Hall illustrated two possible neighborhoods, or groups of pixels, that could be used when processing the image.

46. Hall stated that pixel values may be altered to change the contrast between individual pixels using a linear or a nonlinear transformation. Hall further described performing a transfer, or mapping, function *T* on each input pixel value *f(x,y)* to provide an output pixel value *g(x,y)*. (Hall, p. 160,).[1]

47. Hall demonstrates that, in 1979, it was well-known to use, for contrast enhancement, a transformation function having multiple parts, each transforming an input pixel value by a different amount. (Hall, pages 163-164). The amount by which an input pixel value was changed was selected as a function of the value of the pixel being processed. (Hall, p. 164)

48. The transformation function described by Hall on pp. 163-4 states that an output pixel value, *g*, is based on the value of the input pixel. The input pixel value *f* has a value that ranges from 0 to the maximum input pixel value, f_m. The particulars of the transformation function show below are described in the next three paragraphs.

$$g=\begin{cases}\gamma_1 f+b_1; & 0\le f<f_1;\quad \gamma_1=g_1/f_1,\quad b_1=0,\\ \gamma_2 f+b_2; & f_1\le f<f_2;\quad \gamma_2=\dfrac{g_2-g_1}{f_2-f_1},\quad b_2=g_1-f_1\gamma_2,\\ \gamma_3 f+b_3; & f_2\le f\le f_M;\quad \gamma_3=\dfrac{g_M-g_2}{f_M-f_2},\quad b_3=g_2-f_2\gamma_3.\end{cases}$$



(See Hall, Fig 4.5, p. 159).

[1] In this expression, *x* and *y* represent the location of a pixel in an image and *f(x,y)* represents the value expressed by the pixel at the location *(x,y)*.

49. For input pixel values greater than 0 and less than a predetermined value, f_1, Hall taught that an output pixel value is calculated using the following mathematical function: $g(x,y) = (g_1/f_1)f(x,y) + b_1$. The ratio of g_1/f_1 is the slope of the line defining the transformation function for the range of input values between 0 and f_1. The calculation of g_1 times $f(x,y)$ is a calculated intermediate value, i.e., it is a value that is calculated after receiving the input values but before calculating the final output value, and the value f_1 is a value that falls within a range of possible input pixel values; that is, f_1 is a value that falls within the dynamic range of input pixel values.

50. For input pixel values greater than f_1 and less than a predetermined value, f_2, Hall taught that an output pixel value is calculated using a second mathematical function : $g(x,y) = ((g_2 - g_1)/(f_2 - f_1))f(x,y) + b_2$. The ratio of $(g_2 - g_1)/(f_2 - f_1)$ is the slope of the line defining the transformation function for the range of input values between f_1 and f_2. The calculation $g_2 - g_1$ times $f(x,y)$ is a calculated intermediate value and the value $f_2 - f_1$ is a value that falls within a range of possible input pixel values; that is, $f_2 - f_1$ is a value that falls within the dynamic range of input pixel values.

51. For input pixel values greater than f_2 and less than the maximum value of an input pixel, f_m, Hall explained that an output pixel value is calculated using a third mathematical function: $g(x,y) = ((g_m - g_2)/(f_m - f_2))f(x,y) + b_3$. The ratio of $(g_m - g_2)/(f_m - f_2)$ is the slope of the line defining the transformation function for the range of input values between f_2 and f_m. The calculation $g_m - g_2$ times $f(x,y)$ is a calculated intermediate value and the value $f_m - f_2$ is a value that falls within a range of possible input pixel values, that is, $f_m - f_2$ is a value that falls within the dynamic range of input pixel values.

52. The transformation function described above is known as a "piecewise linear" function because it is made of three linear pieces. Each piece modifies an input pixel value by a

different factor. Hall also taught that a mathematical function that is not piecewise linear but has a nonlinear characteristic, such as a logarithm function or an exponential function, could be used for contrast enhancement. (Hall, pages 165-166).

53. The Hall and Gonzalez textbooks show that many of the elements claimed as new by the '381 patent were, in fact, well-known a decade before the application for the '381 patent was filed. Although I cite specific sections of the Hall and Gonzalez textbooks in this report, those textbooks reflect common knowledge at the time the application for the '381 patent was filed. I may, therefore, rely generally on those texts to support my testimony.

The Lee Publication

54. Another example of well-known techniques for contrast enhancement from this same time period is the article titled, "Digital Image Enhancement and Noise Filtering by Use of Local Statistics," by Jong-Sen Lee, (IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-2, No. 2, pp. 162-168, March 1980) ("Lee").

55. The method taught in Lee for contrast enhancement is similar to a method originally proposed by Wallis in 1976. (Lee, p. 165, col. 2). The method proposed by Wallis was well-known in the literature on digital image processing in the 1970s and 1980s, as indicated by the description and illustrations of the method in the textbook by Pratt (1978) on pages 325 and 326.

56. Lee described systems and methods for transforming in succession a series of input pixel values that collectively define an image. (Lee, col. 1, Abstract). Lee stated that "each pixel is processed independently." (Id.).

57. Lee described pixel values having a value within a dynamic range of values (Lee, p. 166, last paragraph). Lee described grayscale images in which pixels have values between 0 and 255. (Id.).

58. Lee described methods for computing local statistics such as the average luminance of a selected group of pixels around the pixel being processed (the "mean" luminance value) and determining the amount by which the luminance of an individual pixel varied from the average of the luminance of the pixels in its vicinity. Lee does this to enhance image contrast in a selective manner. (Lee, p. 165, col. 2, lines 48-55).

59. Lee explained that the neighborhood or window used to obtain the selected group of pixels could be of different sizes, such as 3×3, 5×5 and 7×7. (Lee, p. 166, col. 1, paragraph after Eq. 5).

60. Lee provided two equations that can be used to calculate average pixel values of a selected group of pixels in a neighborhood. (See Eq. 1 and 2, Lee). The first average value taught by Lee, $m_{i,j}$, is the arithmetic mean of a selected group of pixel values, including the pixel being processed. The mean, by definition, has a value within the dynamic range of the pixel values being averaged. The second average value taught by Lee, $v_{i,j}$, is the variance, in which the squared variation of each pixel value from the average pixel value for the selected group of pixels is averaged. Variance is also a measure of contrast.

61. Lee taught one other local statistic that can be used for contrast enhancement, which is the standard deviation. The standard deviation is the square root of the variance, v_{ij}, which is a measure of the variance of the pixel values from the average value of the pixel values.

62. Lee described how local statistics may be used to achieve contrast enhancement. (Lee, Eq. 3). Lee teaches that a new output pixel value may be calculated by determining the

difference between the input pixel value and the mean value of its neighborhood of pixels. The difference is multiplied by a "gain" factor, *k*. The mean value of the neighborhood of pixels is then added to the results.

63. Thus, Lee shows that local area statistics can be used to selectively enhance the contrast of a digital image.

<u>The Narendra publication</u>

64. In 1981, the article "Real-Time Adaptive Contrast Enhancement", by Patrenahalli M. Narendra and Robert C, Fitch (IEEE Transaction on Pattern Analysis and Machine Intelligence, VOL. PAMI-3, No. 6, pp. 655-661, November 1981 ("Narendra")) was published.

65. Narendra described systems and methods for improving an image by transforming pixel values received as a series of pixel values that collectively define an image. (Narendra, Abstract, Introduction, first paragraph, and Fig. 8).

66. Narendra explained that pixel values are within a dynamic range of values. (Narendra, p. 656, Section 11, first paragraph, and Fig. 1).

67. Narendra described a local contrast enhancement scheme and various computations of local area statistics. (Narendra, p. 656, col. 1, paragraph 3).

68. Narendra said that "the local contrast can be enhanced (by increasing the local gain) without exceeding the dynamic range of the display." (Narendra, p. 656, col. 1, paragraph 5).

69. Narendra explained that the "image intensity [i.e., image luminance] at each point is transformed based on local area statistics – the local mean M_{ij} and the local standard deviation σ_{ij}" computed on a local area surrounding the point" (Narendra, p. 656, col. 2, paragraph 2).

70. Narendra described transforming the input pixel to an enhanced value by subtracting the local mean from the input pixel value, multiplying that amount by a gain factor, $G_{i,j}$, and adding the local mean to the result. The gain factor, $G_{i,j}$, is a ratio of a global mean pixel value to the local standard deviation, σ_{ij}, multiplied by a constant. (Id.) By definition, the standard deviation, as depicted in FIG. 2 of Narendra, is a value that lies within a possible range of values provided by the dynamic range.

71. Narendra illustrated a local area contrast enhancement algorithm, including the above described calculations in FIG. 2 on page 657.

72. Narendra illustrated the implementation in circuitry of their local area contrast enhancement algorithm in Figures 4-6 on page 658.

73. Narendra, like Lee, showed that local area statistics may be used to selectively enhance contrast in a digital image. Narendra also taught that, as early as 1981, it was easy for an algorithm to be constructed as a circuit.

<u>The Wang publication</u>

74. In 1983, the survey article titled, "Digital Image Enhancement: A Survey", by David C. Wang, Anthony H. Vagnucci and C.C. Li, (Computer Vision, Graphics, and Image Processing, Vol. 24, pp 363-381 (1983)) ("Wang") was published.

75. In the abstract, Wang stated that "Over decades, many image-enhancement techniques have been proposed" and "many of these techniques have been implemented." (Abstract, Wang). Wang provided a survey of several techniques for image enhancement. Wang teaches several formulas and methods for rescaling gray levels to achieve contrast enhancement using a wide variety of functions.

76. Wang described systems and methods for enhancing pixel values received as a series of pixel values that collectively define an image. (Wang, p. 363, Introduction, first paragraph, Fig. 1-1).

77. Wang described pixel values having a value within a dynamic range of values (See Wang, p. 363, Notations, "g_{max} is the maximum gray level of the observed image" and "g_{min} is the minimum gray level of the observed image.").

78. Wang described computing an average of the values of a neighborhood of a pixels being processed (See Wang, p. 367, Eqs. (4-1) and (4-2),). "In (4-1), the gray level at *(x, y)* is replaced by the gray level average over a . . . rectangular neighborhood surrounding *(x, y)*." (Id.).

79. Wang presented several linear and nonlinear transformation functions useful for image enhancement (See Wang, p. 372, Figure 5-1). Wang further illustrated in Equations (5-2) and (5-3) several methods to obtain nonlinear transformation functions. The last formula in Equation 5-3 shows a ratio, g_{max}/g_{min}, raised to a power of $P(g(x,y))$ where g_{max} is the maximum value for a pixel, g_{min} is the minimum value of a pixel and $P(g(x,y))$ is a function that varies over the range 0 to 1. After being raised to the power of $P(g(x,y)$, the result is multiplied by g_{min}.

80. Another formula in Equation (5-3) facilitates the selection of a different transformation for each pixel depending upon its value. (See p. 373, Wang). The formula has two stages of nonlinearity, including the calculation of $P(g(x,y))$ and its use as the power factor applied to the ratio g_{max}/g_{min}.

81. As a survey article, Wang shows that different techniques for image processing use similar constituent parts to achieve contrast enhancement and that those parts are often used, or are attempted to be used, interchangeably. Although I cite specific sections of Wang in this report, those textbooks reflect common knowledge at the time the application for the '381 patent

was filed. I may, therefore, rely generally on Wang to support my testimony.

The Rangayyan publication

82. In 1984, I co-authored "Feature Enhancement of Film Mammograms using Fixed and Adaptive Neighborhoods", by Gordon R and Rangayyan RM, Applied Optics, 1984, 23(4): 560-564 ("Rangayyan"). My paper described a method in which "a pixel operator is applied to the image which performs contrast enhancement according to a specified function." (Rangayyan, p. 560, col. 1, lines 22-24). The method described in my paper performs adaptive contrast enhancement, a process by which a different transformation function is selected for each input pixel.

83. My paper described systems and methods for enhancing pixel values received as a series of pixel values that collectively define an image. (See Rangayyan, Section A, Image Acquisition).

84. My paper also described pixel values having a value within a dynamic range of values (See Rangayyan, Section B, Contrast Enhancement, stating "the display range of 0 to 255.").

85. My paper stated that contrast for a pixel is measured as $C = |p-a| / (p+a)$, where p is the value of the pixel being processed and a is the average value of the eight pixels in the immediate vicinity (the 3×3 neighborhood) (see Rangayyan, p. 561, col. 1, ll. 36-40). It further described how the values of p and a are computed using adaptive neighborhoods of different sizes, such as 3×3, 5×5, 9×9 and 15×15. (Rangayyan, p. 561, col. 2. ll. 15-31; see also Figure 1 on p. 561).

86. My paper described a method of increasing the contrast measured, as above, by using a nonlinear mathematical function. It further explains that this function may be varied or

selected as desired. (see Rangayyan, p. 561, col. 1, ll. 36-40, stating "[t]he contrast value is now enhanced according to a specified function to a new value *C'*. A simple enhancement function is $C' = \sqrt{C}$..." .)

87. My paper also described the selection of a transfer function for each pixel being processed as a function of the average value of the selected group of pixels and the value of the pixel being processed. (see Rangayyan, Section B, Contrast Enhancement, 2nd paragraph). The value of the pixel currently being processed is modified by providing a new pixel value from a function selected based on the average value of the pixels near the subject pixel and the value of the subject pixel:

$$p' = a(1 + C')/(1-C') \text{ if } p >= a$$

$$p' = a(1-C')/(1 + C') \text{ if } p < a \quad \text{(Id.)}$$

88. Furthermore, my paper explained how the means and methods described above may be used to achieve adaptive contrast enhancement so as to improve the visibility of objects in images in dark areas as well as in light areas of an image. Examples of results of the application of the methods are given with X-ray images of the breast (mammograms).

89. Rangayyan taught that the size of the neighborhood used to help determine the new pixel value could be itself adaptive.

<u>The Sabri Patent</u>

90. On December 3, 1982, the application for U.S. Patent No. 4,528,584 was filed. The patent was issued on July 9, 1985, and names Mohammed S. Sabri ("Sabri") as the inventor.

91. Sabri described systems and methods for enhancing successively received pixel values that collectively define an image. (see Sabri, col. 3, ll. 18-30, and Figs. 1 and 2).

92. Sabri described pixel values having a value within a dynamic range of values (see Sabri, col. 3, ll. 19-22, "the input signal is in digital form, for example, 8 bits").

93. Sabri described averaging a selected group of pixels around a subject pixel to provide an average according to the formula:

$$\phi_{ij} = \sum_{n=0}^{N_1} \sum_{m=0}^{N_2} a_{nm} X_{i-n,j-m}$$

(Sabri, col. 3, ll 1-4 and 40-45,).

94. Sabri further described deriving from multiple pixels a first signal proportional to the luminance component of the input signal as a computed intermediate value in the form of an average. (Sabri, col. 2, ll. 7-9,). The signal proportional to the luminance component is computed as an average (Φij) of pixel values in an (N_1+1) x (N_2+1) matrix.(Sabri, col. 4, lines 44-46). The input pixel X_{ij} is an element of the matrix and used in computing the average (Sabri, col. 4, lines 46-49).

95. Sabri described determining a level of contrast enhancement as a factor of gamma, γ_{ij} as function of a ratio of the average (Φij) as a numerator over a denominator of the maximum of the dynamic range of the signal R, for example 256 for an 8-bit digital system. (Sabri, col. 4 ll. 26-35).

96. Sabri illustrated in FIG. 1 circuitry for selecting a transfer function as a function of the ratio of the intermediate calculated value - average Φij - and the pixel value currently being processed X_{nm} which also is used in computing the average Φij (see Sabri, elements 10, 12, 14 and 68, FIG. 1).

97. Sabri illustrated in FIG. 1 circuitry for selecting and transforming each input pixel being processed from the selected transfer function as a function of the ratio of an average Φij to the dynamic range R (see Sabri, elements 70, 66 and 68, FIG. 1).

98. Sabri described that the signals being processed may be analog or digital in performing contrast enhancement techniques. (Sabri, col. 3, lines 18-30).

99. Sabri taught a local contrast enhancement algorithm that uses the dynamic range in the denominator of a transfer function.

The Richard Patent

100. United States Patent No. 4,654,710 to Christian J. Richard ("Richard") was issued as a patent on March 31, 1987 based on an application filed on January 3, 1986.

101. Richard described a contrast amplifier for improving the quality of images. (see Richard, Field of the Invention).

102. Richard explained that it is "a known practice to enhance or amplify the contrast of video images by increasing the gain of transmitted luminance signals representing the images." (Richard, col. 1, lines 12-15).

103. Richard described systems and methods for continuously enhancing pixel values received as a successive series of pixel values that collectively define an image. (see col. 2, ll. 26-34, Richard, see Brief Description of the Drawings and Figure 1).

104. Richard described pixel values having a value within a dynamic range of values (see Richard, col. 3, ll. 33-47, col. 5, l. 66 – col. 6, l. 19, and Figure 1).

105. Richard described averaging a selected group of pixels to provide an average pixel value, such as the global mean or local mean. Richard describes "a means for estimating a mean value M_g of luminance of all points of each image in succession." (Richard, col. 1, lines

62-63). This refers to the global mean. Richard further describes "a means for computing a local mean value M_v of luminance of a point being processed." (Richard, col. 1, lines 62-63). This refers to the local mean.

106. Richard described "a means for multiplying the value of luminance of the point being processed by a variable coefficient which is proportional to the ratio M_v/M_g." (Richard, col. 1, lines 66-68). The ratio M_v/M_g has a numerator that is the average value of pixels, in a local region of the pixel being processed and a denominator that is a value in the range of possible values of the dynamic range (the global mean). The value M_v is both an average and an intermediate calculated value. The value M_g is both a value in a range of possible values and a value within the dynamic range.

107. Richard illustrates circuitry and devices that use the ratio M_v/M_g for performing contrast enhancement. Block 5 of the Figure includes circuit components for selecting a transfer function based on the input value Y_{ij} and an average M_g (see Richard, Figure 1, output from element 10). The circuitry transforms the value of the pixel being processed to an enhanced output value based on the selected transfer function and a ratio of an average value for a group of pixels adjacent to the subject pixel M_v over a value in the dynamic range, M_g, the global mean. (see Richard, Figure 1, output 13).

108. Richard explains that "the effect of the contrast amplifier is …to reduce the luminance of the current point in order to bring it close to the value of black or respectively to increase said luminance in order to bring it close to the value of pure white." (Richard, col. 5, l. 66 – col., 6, l. 3).

109. Richard described a circuit for local area contrast enhancement that calculates local mean values for groups of pixels and the use of a user-controllable constant for controlling the amount of gain applied to an image.

The Chen Patent

110. United States Patent No. 4, 789,933 to Chen et al. ("Chen") was issued on December 6, 1988 based on an application filed on February 27, 1987

111. Chen describes systems and methods for continuously enhancing pixel values received as a successive series of pixel values that collectively define an image. (see Chen, col. 1, l. 62 – col. 2 l. 3, col. 4, ll. 45-65 and Fig. 1).

112. Chen describes pixel values having a value within a dynamic range of values (see Chen, col. 1, l. 62 – col. 2, l. 3).

113. In the Abstract, Chen describes computing "the mean of pixel values of neighboring pixels" (Chen, Abstract).

114. Chen also describes, in the Abstract, selecting a transfer function uniquely defined for each pixel being processed and using the mean of pixel values of neighboring pixels. (Id.).

115. Chen describes "an image improvement means for replacing each pixel value by a weighted combination of the replaced pixel value and an average of the surrounding pixels." (Chen, col. 9, ll. 59-63).

116. Chen further describes processing and averaging selected groups of neighboring pixels in two rings that surround the pixel being processed (Chen, col. 6, ll.18-60 and col. 10, ll. 20-29; see also Figure 2). Chen describes computing a contrast-related measurement using a ratio of the average value of the difference between pixel values selected from the rings. (Id.) This ratio has an intermediate calculated value of a first average of the difference between pixel values as a numerator over a value that lies within the possible values of the dynamic range.

117. Chen further describes that the transfer function is derived from the ratio of comparing (i) a variation between the pixel value being processed and the average pixel value of pixels in the first ring to (ii) a variation between the pixel value being processed and the average pixel value of pixels in of the second ring. (Id.).

118. Chen describes transforming each pixel value with an improved pixel value using the transfer function and ratios described above. (Id.)

119. Chen teaches that, by 1987, the state of the art in digital image processing had advanced beyond "simple" statistical functions for local area contrast enhancement. Chen describes using multiple averages and fractals for local area contrast enhancement.

120. A list of the references I used in forming this Opinion is attached as Exhibit B.

121. In my digital image processing course taught to university students from 1983 to 1987, a typical student would learn and understand these digital image processing techniques. That is, the state of the art in digital image processing prior to the time of filing of the application for the '381 patent made it well-known: to sharpen an image or enhance the contrast of the image; to detect edges as part of contrast enhancement; to apply various mathematical transformations to determine an average of a selected group of pixels, including the pixel being processed; choose a gamma transfer function based on the average value of a neighborhood of pixels adjacent to the pixel being processed; use a ratio in a transformation function; and transform the pixel being processed based on the gamma value produced by the gamma transfer function.

122. In my opinion, in 1988 and 1989, in the context of the '381 patent, a person of ordinary skill in the art would typically have a Bachelor's degree in electrical engineering and two years of coursework or practical experience directed to digital signal or image processing.

III. THE '381 PATENT

123. The application for the '381 patent was filed on April 18, 1988. The '381 patent issued on May 9, 1989, and is titled, "System and Method for Electronic Image Enhancement by Dynamic Pixel Transformation." It names as inventors Woo-Jin Song and Donald S. Levinstone.

124. I have read, and understood, the '381 patent and its prosecution history. I have been asked to review claims 1-3 and 7-9 of the '381 patent.

125. Claims 1 and 7 of the '381 patent are "independent" claims. Claims 2 and 3 depend on claim 1. Claims 8 and 9 depend on claim 7.

126. As originally filed on April 18, 1988 claim 1 read:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:
>
> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged; and
>
> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel.

As originally filed, Claim 7 of the '381 patent, then numbered claim 8, read:

> A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising the steps of:

> averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;
>
> selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and
>
> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel.

127. On October 12, 1988, the Examiner rejected claims 1 and 8 as unpatentable over United States Patent No. 4,489,349 to Okada ("Okada"). The examiner stated:

> Okada discloses a video brightness control circuit having an average picture level of detector 20 which averages input picture information and provides a control signal to a variable correction circuit 10. The variable correction circuit operates on the input-output signal to vary the characteristic of the input-output signal as a function of the detected average picture level detector (see Fig. 2). Okada controls the relative brightness of the video signal such that the picture areas containing most of the picture information are corrected to give greater contrast. Although, Okada does not identically disclose all the element [sic] as recited in claims 1, 2, 8 and 9, Okada does provide a system which attempts to achieve the same results as the applicant. Both systems show an averaging circuit and a correction circuit which use the averaged information to produce an output which follows the slopes of the curves shown in Figure 2 of the present invention and Figure 2 of Okada.

128. I have reviewed the Okada patent and agree, generally, with the Examiner's comments that Okada shows an averaging circuit and a correction circuit that uses the averaged information.

129. In response to this rejection, the applicant did not disagree with the Examiner's analysis. Instead, the applicant amended claim 1 of the '381 patent to add the following elements (underlining shows new elements):

> (Amended) A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal <u>having a value within a determinate dynamic range of values and</u> corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:
>
> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged; and
>
> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel <u>wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.</u>

Claim 1 then issued in this form.

130. In response to the rejection of claim 8 over the Okada reference, the applicant amended claim 8 to include the following elements (underling shows added elements):

> (Amended) A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal <u>having a value within a determinate dynamic range of values and</u> corresponding to one of a plurality of succeeding pixels

> which collectively define an image, said method comprising the steps of:
>
> averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;
>
> selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and
>
> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel <u>wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.</u>

Claim 8 then issued in this form, renumbered as claim 7.

131. Although Okada and the '381 patent produce similar nonlinear transformation results using an average-based gamma function, the '381 patent appears to have been allowed by the patent examiner because Okada does not explicitly disclose the language added to claims 1 and 7 of the '381 patent, i.e., a ratio of the value of an average signal to a value proportionate of the dynamic range of the signals to generate the nonlinear transformation illustrated in FIG. 2 of the Okada patent and FIG. 2 of the '381 patent.

132. However, that element, along with the other elements of claims 1 and 7, were well-known at the time the '381 patent was filed. The patents and references I discuss below were not considered by the Examiner during the examination of the application for the '381 patent.

IV. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION USING THE CLAIM CONSTRUCTIONS PROPOSED BY POLAROID

133. In my review of claims 1-3 and 7-9 of the '381 patent, I have been told that if each element of a claim is found in a single prior art reference, the claim is invalid for what is called anticipation. I understand that for the claim to be anticipated, all of its requirements must have existed, expressly or inherently, in a single item of prior art. I have also been told that a claim is "obvious" if one of ordinary skill in the art would be motivated to modify an item of prior art, to combine two or more items of prior art to arrive at the claimed invention. When a patent simply arranges old elements with each performing the same function it had been known to perform and yields no more than one would expect from such an arrangement, the combination is likely to be obvious. In certain circumstances, the fact that a combination was obvious to try might show that it was obvious. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp.

134. I understand that HP and Polaroid have proposed different constructions of the disputed claims and that the Court has not yet ruled on the proper interpretation of these claims. I provide the following assessment of the novelty and obviousness of claims 1-3 and 7-9, on the assumption that the Court adopts Polaroid's proposed construction of the claims. Using Polaroid's proposed claim meanings, I believe that claim 7 of the '381 patent is anticipated by any one of Gonzalez[2], the Gonzalez algorithm[3], Richard[4], Lee[5], Sabri[6], Rangayyan[7], Chen[8],

[2] A chart identifying how Gonzalez teaches each and every element of claims 1 and 7 of the '381 patent and suggests the elements of claims 2-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix C.

[3] A chart identifying how the Gonzalez algorithm teaches each and every element of claim 7 of the '381 patent and suggests the elements of claims 2 and 3, as those claims are proposed to be understood by Polaroid, is attached as Appendix B.

Narendra[9] and Wang[10]. Further, claim 8 of the '381 patent is anticipated by Richard or Rangayyan. Claim 9 anticipated by Richards are obvious in view of any one of Gonzalez, Lee, Narendra, and Wang. Claim 1 is obvious in view of the Gonzalez algorithm in combination with any one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen or Narendra. Claim 2 is obvious in view of the Gonzalez algorithm, combined with any one or Gonzalez, Richard, Rangayyan, Lee, or Narendra. Claim 3 is obvious in view of the Gonzalez algorithm, combined with any one of Gonzalez, Richard, Lee or Narendra.

135. I first assess claim 7, which is a method claim consisting of a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

<u>A method for continuously enhancing . . . .</u>

136. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

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[4] A chart identifying how Richard teaches each and every element of claims 1-3 and 7-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix E.

[5] A chart identifying how Lee teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix F.

[6] A chart identifying how Sabri teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix G.

[7] A chart identifying how Rangayyan teaches each and every element of claims 7-8 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix H.

[8] A chart identifying how Chen teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix I.

[9] A chart identifying how Narendra teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix J.

[10] A chart identifying how Wang teaches each and every element of claim 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix J.

137. I understand Polaroid's position to be that the preamble should not be considered an element of claim 7. However, I also understand that, in the event the preamble of claim 7 is found to be element of the claim, Polaroid believes that *"continuously enhancing"* should be construed to mean "successively transforming" and that *"electronic information signals*" should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values." See Joint Claim Construction Statement (Corrected).

138. Polaroid also believes that the term *"electronic image data received in a continuous stream of electronic information signals"* that appears in the preamble should be construed as "electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" and that the term *"each signal having a value within a determinate dynamic range of values"* should be construed as "each signal being associated with a value that lies within a range of possible values bounded by definite limits." (Id.)

139. As construed by Polaroid, the elements of the preamble are taught by each of Gonzalez, the Gonzalez algorithm Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

140. Gonzalez teaches methods for enhancing image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a

number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel *(x,y)*. Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

141. The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.

142. Richard teaches methods for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and

all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

143. Lee teaches methods for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.

144. Sabri teaches methods for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element

values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.

145. Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to "0" and all six bits of the value equal to "1." Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

146. Chen teaches methods for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

147. Narendra teaches methods for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p.

656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

148. Wang teaches digital enhancement techniques to improve picture quality. (Wang, p. 363, Introduction, line 1). Wang defines an image as a collection of pixels, each pixel at a coordinate *x* and *y* in a rectangular representation of an image. (Wang, p. 365, Section 2. Notation; Figures (4-1), (4-2) and (4-3)). Each of the pixels has a value representing a gray level that lies within a minimum and a maximum gray level of the image. (Wang, p. 365, Section 2, Notation). Thus, the value of a pixel lies within a range of possible values defined by the bounds of a minimum value and a maximum value. Each pixel is processed sequentially. (Wang, Eq. 6-4). Therefore, Wang teaches successive transformation of luminance image data defining an original image, each luminance signal having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

...averaging the electronic information signals....

149. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

150. I understand that Polaroid contends that "*averaging*" should be construed to mean "calculating an intermediate value" and that "*average electronic information signal*" should be construed to mean "the signal providing pixel information, such as a color, luminance, or chrominance value of the calculated intermediate value." *See* Joint Claim Construction Statement (Corrected).

151. As construed by Polaroid, this step reads as calculating an intermediate value for a selected group of pixels and providing the intermediate calculated value for each of the groups of pixels. Such methods are taught by each of Gonzalez, the Gonzalez algorithm Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang

152. Gonzalez teaches computing an average value for a selected group of pixels and providing the average value for each group of pixels referred to in Gonzalez as *m(x,y)*. (Gonzalez, pp. 158-163). A neighborhood averaging technique calculates an average luminance value by averaging the luminance values of a selected group of pixels referred to as a neighborhood. (Gonzalez, p. 161, Section 4.3.1, first paragraph). The neighborhood of pixels may be a square, such as a 3 by 3 matrix surrounding a pixel that includes the pixel itself. (Id.) The average is calculated by adding the luminance values of the pixels in the neighborhood and dividing by the number of pixels in the neighborhood. (Gonzalez, p. 161, Equation (4.3-1)). This calculation produces an intermediate calculated value providing pixel information. Thus, Gonzalez teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

153. The Gonzalez algorithm teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value for each of the group of

pixels. The Gonzalez algorithm computes a calculated intermediate value for a group of pixels using the following function, *SS:*

$$SS=(-1/GN) * \text{ALOG}\ (FH/T)$$

GN contains a value of 32, representing the maximum value of the dynamic range of the intended output device (in this case, a line-printer). *FH* represents the maximum gray level value of the group of pixels representing the input image. (Gonzalez, p. 453, line 4). *T* represents the minimum gray level of the group of pixels representing the input image (Gonzalez, p. 453, line 3). The Gonzalez algorithm therefore, teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value . In this case, a logarithmic function, ALOG, of the ratio of *FH to T.*

154. Richard teaches "a means for computing a local mean value M_v of luminance of a point being processed." (Richard, Col. 1, ll. 62-63). A horizontal filtering device and a vertical filtering device as shown in Figure 1 of Richard are connected in series to produce the local mean value M_v. (Richard, col. 4, ll. 46-53). The filtering devices receive a sequence of numerical luminance values of points in a field representing an image. Each field of the image consists of multiple lines, for example, 256 lines, and each line has multiple points or luminance values, for example, 512 points. (Richard, col. 3, ll. 32-43). The filtering devices of Richard compute the local mean value for a line from the luminance values of points on the line. (Id.). The local mean value is provided as the mean for the selected group of luminance values. (Richard, see output M_v from element 6 in the single Figure). The local mean value produced by the filtering devices is an expression of the mean value that would be obtained by computing an arithmetic mean. (Id.). Richard, therefore, teaches calculating an intermediate value (in this case, the local mean) for each selected groups of pixels that provides pixel information.

155. Lee teaches a method in which a mean value for each input pixel is derived from the local mean of all pixels within a fixed range surrounding the input pixel. (Lee, p. 165, Abstract, ll. 8-10; p. 165, col. 2, Introduction, ll. 17-22). A two-dimensional array stores a luminance value for each pixel of an image. (Lee, p. 165, col. 2, last paragraph). A local mean $m_{i,j}$ is calculated over a window having a predetermined number of rows and columns. (Lee, p. 166, Equation 1). The window is a rectangular region surrounding the input pixel. Equation 1 sums all the luminance values in the surrounding region and divides by the total number of values in this region (Id.). Lee, therefore, teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

156. Sabri teaches computing for a pixel an average of luminance values of neighboring pixels. (Sabri, Abstract). The summing means of Figure 1 serves to compute, for a group of pixels, a weighted average according to the identified formula. (Sabri, col. 3, 38-47). This weighted average is an intermediate calculated value that provides pixel information. Therefore, Sabri teaches calculating an intermediate value for a selected group of pixels that provides pixel information.

157. Rangayyan teaches calculating average pixel value of a group of pixels in a region surrounding the pixel being processed. (Rangayyan, p. 561, col. 2, Section C, first paragraph). Therefore, Rangayyan teaches calculating an intermediate value (in this case, an average) that provides pixel information.

158. Chen teaches computing the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Chen, Abstract, 10-13). The image enhancing circuit (Chen, Fig. 1, element C) of Chen includes a pixel value averaging means (Chen Fig. 1, element 40) to generate a mean pixel value. (Chen, col. 5, ll. 25-27). By way of example in Figure 2, a mean

value is computed to represent the average of 25 pixel values in a 5 by 5 neighborhood centered around a pixel being processed. (Chen, col. 5, ll. 39-42). This average is a calculated intermediate value and is provided for the group of pixels of the surround region. Chen, therefore, teaches a calculated intermediate value (in this case, an average) for each group of pixels that provides pixel information.

159. Narendra teaches calculating a local mean for a pixel, referred to as M_{ij}, for a local area surrounding the pixel. (p. 656, col. 2, ll. 3-6). Narendra, therefore, teaches an intermediate calculated value (in this case, a mean) for each group of pixels that provides pixel information.

160. Wang teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Wang, p.367, first paragraph). Wang takes an average (i.e., an intermediate calculated value) over a rectangular neighborhood surrounding the pixel being processed. (Id.; Equation (4-1) and (4-2)). Therefore, Wang also teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels

<u>...selecting one of a plurality of different transfer functions....</u>

161. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

162. I understand that Polaroid construes this step to mean: "selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner

whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel". *See* Joint Claim Construction Statement (Corrected).

163. As construed by Polaroid, this step means that a transfer function is selected for each pixel being processed that is a function of (1) the input pixel value and (2) the calculated intermediate value for the group of pixels containing the input pixel. The calculated intermediate value is produced from the "averaging" step of this method discussed above. The transfer function is any function that transforms the pixel being processed. Thus, according to Polaroid, any function that transforms a pixel being processed using (1) the value of the pixel and (2) the calculated intermediate value satisfies this claim element. Such functions are taught by each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

164. Gonzalez teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Gonzalez, p.159, last paragraph to p. 160, first and second paragraph). The value of the pixel being processed, referred to in Gonzalez as $f(x,y)$, is transformed into a new pixel value, referred to as $g(x,y)$ using the transfer function illustrated by Equation (4-2-14). (Gonzalez, p. 160). This transfer function uses the value of the pixel $f(x,y)$ in its computations. This transfer function also uses the calculated intermediate value - the mean of the pixel values for a group of pixels including the pixel being processed, referred to as $m(x,y)$ in its computation. The result of this computation using the value of the pixel $f(x,y)$ and the average value $m(x,y)$ results in a transformed value for the pixel $g(x,y)$. Therefore, Gonzalez teaches selecting a transfer function for the pixel being processed using the value of

the pixel and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

165. The Gonzalez algorithm teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which in this case, ALOG (*FH/T*). The Gonzalez algorithm provides the following transfer function:

$$FLEV = FH * \text{EXP}(SS*(GN-I)) + 0.5$$

(Gonzalez, p. 454, see computation of variable SS). *I* represents the input pixel value. GN represents the maximum value of the dynamic range of the intended output device. *SS* is a function computed as follows:

$$SS = (-1/GN) * \text{ALOG}\ (FH/T)$$

(Gonzalez, p. 454, see computation of variable SS). Gonzalez, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel *I*, and the calculated intermediate value, ALOG (*FH/T*).

166. Richard teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Richard, Fig. 1). As shown in Figure 1, the value Y_{ij}/M_g is generated from the multiplier component (Richard, Fig. 1, 10) and is dependent on the pixel value Y_{ij}. Richard teaches that the calculated local mean, M_v, is then multiplied by that result. Richard teaches, therefore, selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which is the local mean value, M_v.

167. Lee teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Lee, p. 166, Section II, ll. 3-5, Eq. 4). This

algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Lee, p. 166, ll. 1-4 after Eq. (4)). Lee teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

168. Sabri teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Sabri is an average of the pixel values preceding the pixel being processed. (Sabri, col. 2, ll. 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value, C_{ij}. (Sabri, col. 2, ll. 29-39). The contrast enhancement factor is then added to a calculation that includes the intermediate calculated value, i.e., the average ϕ of the pixels preceding the pixel being processed. Sabri, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which for Sabri is the average value of the pixels preceding the pixels being processed.

169. Rangayyan teaches selecting a transfer function based on the input pixel value and a calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, a. Rangayyan states that a contrast enhancement factor, C, is calculated using the value of the pixel being processed, p, and the average, a, of a group of pixels in the neighborhood around p. The contrast factor is used, as part of a final transformation equation, to transform each pixel value. Therefore, Rangayyan teaches selecting a transfer function for the pixel being processed using the value of the pixel and calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, a.

170. Chen teaches selecting a transfer function for each pixel based on the pixel value and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Abstract, Chen). A transfer function provides an improved pixel value by subtracting the mean neighborhood value from the value of the pixel. (Chen, col. 8, l-11; Eq. 11). This difference between the pixel value and the intermediate calculated value is multiplied by a transfer function. (Id.). Therefore, Chen teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood.

171. Narendra teaches selecting a transfer function for the pixel being processed based on the pixel value and the calculated intermediate function which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed. (Narendra, p. 656. Section II, paragraph 5). In the transformation formula of Equation 1, this intermediate calculated value is subtracted from the pixel value. (Narendra, p. 656, col. 2, Eq. 1). This difference is multiplied by a variable gain function. Therefore, Narendra teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed.

172. Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4

after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

<u>...transforming the electronic information signal...</u>

173. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

174. Polaroid provides the following definition for the transformation step:

> transforming the signal providing pixel information ... corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value. *See* Joint Claim Construction Statement (Corrected).

175. As construed by Polaroid, this step states that the pixel being processed is transformed using the selected transfer function, provided that the transfer function is further selected as a function of a ratio of a calculated intermediate value over any value within a range of possible values bounded by definite limits. That is, the function that transforms the input signal is further selected a function of the following ratio:

calculated intermediate value / a value within a range of values.

176. As construed by Polaroid, functions of this type are taught by each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

177. Gonzalez teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the values for a group of pixels that includes the subject pixel) over a value that lies within a range bounded by definite

limits. The value of the pixel being processed, referred to as *f(x,y)*, is transformed into a new pixel value, referred to as *g(x,y)* using the following transfer function illustrated by Equation (4-2-14):

$$g(x, y) = A(x, y) \times [f(x, y) - m(x, y)] + m(x, y).$$

(Gonzalez, p. 160).

The transformation function *g(x,y)*, therefore, transforms an original pixel value into a new pixel value using a gain referred to as *A(x,y)* that is defined as follows:

$$A(x, y) = \frac{k \times M}{\sigma(x, y)} \text{ for } 0 < k < 1.$$

(Id.).

When the gain *A(x,y)* is replaced with its definition in the equation, the transfer function becomes:

$$g(x, y) = \frac{k \times M}{\sigma(x, y)} \times [f(x, y) - m(x, y)] + m(x, y)$$

which, in turn, may also be represented as:

$$g(x, y) = \frac{k \times M \times f(x, y)}{\sigma(x, y)} - \frac{k \times M \times m(x, y)}{\sigma(x, y)} + m(x, y).$$

The equation above shows that *f(x,y)* is transformed into *g(x,y)* using a function selected as a ratio of the mean of pixel values for a group of pixels that includes the subject pixels over the standard deviation, *σ(x,y)* of the pixels in the group. The standard deviation is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Gonzalez, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean of the pixel

values for a group of pixels that includes the subject pixel) over a value within a range of values (in this case, the standard deviation of the pixels in the group).

178. The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, *I*, into an output pixel value *FLEV* as follows:

$$FLEV = FH * \mathrm{EXP}(SS*(GN-I)) + 0.5$$

(Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (*FH/T*) over a value in the range of values because the function SS is computed as follows:

$$SS = (-1/GN) * \mathrm{ALOG}\ (FH/T)$$

(Gonzalez, p. 454, see computation of variable SS). *GN* represents the maximum value of the intended output device. *GN*, therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, *I*, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (*FH/T*) over a value in the range of values (in this case, *GN*).

179. Richard teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values (in this case, the local mean value for a group of pixels M_v) over a value that lies within a range bounded by definite limits. Richard transforms an input signal using the function depicted as element 5 in Figure 1:

$$Y'_{ij} = Y_{ij} \times \frac{M_v}{M_g} \times k\ .$$

(Richard, col. 2, ll. 21-25; Fig. 1).

In Figure 1, Richard illustrates the use of the pixel value (referred to as Y_{ij}), a local mean value of a group of pixels, M_v, and a ratio of the local mean value to the global mean value (M_v/M_g) to produce the transformed value of Y_{ij} times the ratio of M_v/M_g and a constant K. (Richard, Figure 1, elements 10-14). The global mean M_v is an intermediate value providing pixel information. (Richard, col. 1, ll. 58-68). The denominator of this ratio, M_g, has a value within a range of possible values. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Richard, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean value M_v) over a value within a range of values (in this case, the global mean value, M_g).

180. Lee teaches transforming an input signal where the transfer function is further selected as a ratio a calculated intermediate value (in this case, the local mean of the pixel values for a group of pixels including the input pixel) over a value that lies within a range bounded by definite limits. The following algorithm of Lee transforms the input pixel by subtracting the local mean from the value of the pixel, multiplying this difference by a gain k and adding the result to the local mean to provide the transformed pixel value $x'_{i,j}$:

$$x'_{i,j} = m_{i,j} + k(x_{i,j} - m_{i,j}) \quad \text{where } k = \sqrt{\frac{v_{i,j}}{v_{orig}}}$$

(Lee, p. 166, Equation (4)).

In the above equation, $x_{i,j}$ represents the value of the input pixel and $m_{i,j}$ the local mean for the pixel at (i,j). The calculation $x_{i,j} - m_{i,j}$ subtracts the local mean from the value of the pixel being processed. The local mean is an intermediate calculated value of a selected group of pixel values including the input pixel. (Lee, p.165, col. 2 last paragraph and p. 166, Equations (1) and (2)). The result of the subtraction operation is multiplied by a gain referred to as k. The gain k is

defined as a ratio of a local standard deviation (i.e., square root of local variance of pixels in a group of pixels) to an original standard deviation (i.e., square root of original variance of pixels in a group of pixels). (Id). When the gain *k* is replaced with its definition in the above equation, the transformation function becomes:

$$x'_{i,j} = m_{i,j} + \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot x'_{i,j} - \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot m_{i,j}$$

The standard deviation (i.e., the square root of a variance) is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Lee, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local means value, $m_{i,j}$) over a value within a range of values (in this case, the original standard deviation).

181. Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the mean of the pixel values for a group of pixels preceding the pixel being processed) over a value that lies within a range bounded by definite limits. Sabri transforms an input signal using the transformation function, B_{ij}, γ

$$Bij = \gamma ij + \left(\frac{1-2\gamma ij}{R}\right)\phi ij$$

(Sabri, col. 2, ll. 40-46).

In the equation above ϕ_{ij}, is a weighted average of picture element values, which is the calculated intermediate value providing pixel information. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). *R* is the maximum range of input picture element values. (Sabri, col. 2, ll. 40-46). Expanding this expression gives:

$$Bij = \gamma ij + \frac{\phi ij - 2\times\phi ij\times\gamma ij}{R} \quad \text{or} \quad Bij = \gamma ij + \frac{\phi ij}{R} - \frac{2\times\phi ij\times\gamma ij}{R}$$

Therefore, Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (the weighted average, ϕ_{ij}) over a value within a range of values (in this case, the maximum value of the dynamic range, R).

182. Rangayyan teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value over a value that lies within a range bounded by definite limits. (Rangayyan, p. 561, Section C, Contrast Enhancement). Rangayyan computes a contrast measure C using the input pixel value, p, and the average value, a, of the values of the pixels surrounding p:

$$C = \frac{|p-a|}{(p+a)}$$

(Rangayyan, p.561, col. 2).

A new pixel value is calculated from the square root of C, referred to as C', and the average a as follows:

$$p' = a\times\frac{(1+C')}{(1-C')} \text{ if } p \geq a\text{, and also } p' = a\times\frac{(1-C')}{(1+C')} \text{ if } p < a$$

Expanding the transfer mathematically gives:

$$p' = a\times\frac{1+\sqrt{\frac{|p-a|}{(p+a)}}}{1-\sqrt{\frac{|p-a|}{(p+a)}}} \text{ for } p \geq a\text{, and } p' = a\times\frac{1-\sqrt{\frac{|p-a|}{(p+a)}}}{1+\sqrt{\frac{|p-a|}{(p+a)}}} \text{ for } p < a$$

The transfer function *p'* is then used in a transformation function, *p"*, as follows:

$$p" = 255 \times \frac{(p' - \min)}{\max - \min} \text{ for positive mode}$$

$$p" = 255 \times \frac{(\max - p')}{(\max - \min)} \text{ for negative mode}$$

(Id.).

Max refers to the maximum pixel value and min refers to the minimum pixel value. Replacing *p'* in this equation with its definition above gives:

$$p" = 255 \times \frac{\left(a \times \frac{1 + \sqrt{|p-a| / (p+a)}}{1 - \sqrt{|p-a| / (p+a)}} \right) - \min}{\max - \min} \text{ for positive mode and}$$

$$p" = 255 \times \frac{\max - \left(a \times \frac{1 - \sqrt{|p-a| / (p+a)}}{1 + \sqrt{|p-a| / (p+a)}} \right)}{\max - \min} \text{ for negative mode}$$

The contrast measure *C*, which is the ratio of the absolute value of the difference $|p - a|$ over *(p+ a)* is the calculated intermediate value providing pixel information. The value "*max – min*" represents a value within a range of possible values. Therefore, Rangayyan teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the contrast measure, C,

which is itself a function of the mean of the pixel values of a group of neighboring pixels) over a value within a range of values (in this case, *max-min*).

183. Chen teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a selected group of pixels in the neighborhood of the input pixel) over a value that lies within a range bounded by definite limits. Chen uses the following function to replace each input pixel value *I(i,j)* with an improved pixel value *I'(i,j)*:

$$I'(i,j) = G(i,j) \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$

(Id.).

G(i,j) refers to a gain function and $\overline{I(i,j)}$ is a mean of pixel values of neighboring pixels. Chen teaches that the transfer function *G(i,j)* may be expressed as:

$$G(i,j) = \frac{\log(n) - \log(m)}{\log K(n) - \log K(m)}$$ in which *K(n)* and *K(m)* are average differences between the pixel at *(i,j)* and the values of the pixels lying within two circular areas having radius of *n* and *m*, respectively.

Replacing the value of *G(i,j)* in the transform function $\overline{I(i,j)}$ with its expression, the equation becomes:

$$I'(i,j) = \frac{\log(n) - \log(m)}{\log(K(n) - \log(K(m))} \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$

This same equation may be represented as:

$$I'(i,j) = \frac{\{\log(n) - \log(m\} \times I(i,j)\}}{\log(K(n)) - \log(K(m))} - \frac{\{\log(n) - \log(m\} \times \overline{I(i,j)}\}}{\log(K(n)) - \log(K(m))} + \overline{I(i,j)}$$

Chen, therefore, teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this

case, the mean value, $\overline{I(i,j)}$, of pixels in the neighborhood of the input pixel) over a value within a range of values (in this case, the difference of the logarithmic value of the first average difference and the logarithmic value of the second average difference (i.e. *log(K(n))-log(K(m))*).

184. Narendra teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a local group of pixels, M_{ij}, over a value that lies within a range bounded by definite limits. The following transformation function uses the pixel value I_{ij} of the pixel being processed and a mean value M_{ij} to provide the improved pixel value $\hat{I}_{ij}$:

$$\hat{I}_{ij} = G_{ij}(I_{ij} - M_{ij}) + M_{ij}$$

(see Narendra, p. 656, Equation (1)).

G_{ij} is a gain factor. The local mean value M_{ij} is an intermediate calculated value computed on a group of pixels surrounding the pixel being processed. (Narendra, p. 65, first paragraph). The transformation function takes the difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}.

$$G_{ij} = \alpha \frac{M}{\sigma_{ij}},\quad 0 < \alpha < 1$$

(Id.)

When the gain G_{ij} is replaced with its definition in the above equation, the transformation function becomes:

$$\hat{I}_{ij} = (\alpha \frac{M}{\sigma_{ij}} \cdot I_{ij}) - (\alpha \frac{M}{\sigma_{ij}} \cdot M_{ij}) + M_{ij}$$

which, in turn, becomes:

$$\hat{I}_{ij} = \left(\frac{\alpha \cdot M \cdot I_{ij}}{\sigma_{ij}}\right) - \left(\frac{\alpha \cdot M \cdot M_{ij}}{\sigma_{ij}}\right) + M_{ij}$$

The σ_{ij} is the standard deviation of local pixel values, α is a gain factor and M is the global mean. Therefore, Narendra teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the local mean value, M_{ij}) over a value within a range of values (in this case, a standard deviation value).

185. Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4 after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

186. Because each and every element of claim 7 can be found in any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang, I am of the opinion that claim 7 is anticipated, as that concept has been explained to me, by each one of those references.

187. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

188. Claim 8, therefore, requires a method having all the elements of claim 7 and the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition. Such functions are taught by Richard or Rangayyan and are suggested by any one of Gonzalez, Lee, Narendra or Wang.

189. Richard teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors when the local mean, M_v, represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of *Mv/Mg* will be very close to 0 (for very dark pixels) and will be large for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for that pixel and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for that pixel. The darkest areas will be made darker relative to less dark areas and the lightest areas will be made lighter relative to less light areas. Richard, therefore, teaches selecting the transfer function to provide higher contrast to a pixel when a calculated intermediate value represents a very dark or very light condition.

190. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $|p\text{-}a|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C,* will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

191. Because Richard and Rangayyan both disclose each and every element of claim 8 of the '381 patent, I believe that Richard or Rangayyan anticipates claim 8, as it is proposed to be construed by Polaroid.

192. Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, *A(x,y).* (Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, *K,* by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq.

4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, M, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor taught by Gonzalez to further increase the contrast of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of the image using with the mean value of the neighboring pixels. In this way the gain would increase in areas of low light or high light. Therefore, I believe that claim 8 is obvious in view of Gonzalez.

193. Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph). "The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 8 is an obvious extension of Lee.

194. Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, M, is a constant value for an image. I believe that it would have

been obvious to try modifying the gain factor taught by Narendra to further increase the content of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of image using the mean value of the neighboring pixels. In this matter the gain would increase in areas of low light or high light. Therefore, I believe claim 8 is obvious in view of Narendra.

195. Wang teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Wang teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Wang, p. 166, col. 1, last paragraph). "The linear function ... yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increases the "stretch" in areas of very low light or very high light, because that would allow Wang to further increase contrast at both ends of the gray scale.

196. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

197. Claim 9, therefore, recites a method having all the elements of claim 8 and claim 7, and the element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function. Such functions are taught by Richard and are suggested by any one of Gonzalez, Lee, Narendra or Wang.

198. Richard teaches a system in which a constant value, *K*, can be adjusted by an operator "to control the contrast." (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value, *Yij*, multiplied by *(Mv/Mg)*, and further multiplied by a constant *K* (Richard, Fig. 1). An increase in *K* will increase the constant between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the lightest areas of an image, and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

199. Because Richard teaches each and every element of claim 9 of the '381 patent, I am of the opinion that Richard anticipates claim 9, as that claim is proposed to be construed by Polaroid.

200. Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function *g(x,y)* applies a local gain factor *A(x,y)* to the difference between the pixel value being processed *f(x,y)* and the local mean *m(x,y)* of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor *A(x,y)* amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

201. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a higher output pixel value than a lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

202. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by multiplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Narendra.

203. Wang teaches using the contrast gain factor of a constant k as also taught by Lee. (Wang, p. 376, Equation (6-4)). As in Lee, Wang teaches that a constant k is multiplied by the difference between the value of the pixel itself g(x,y) and the mean value of the pixels surrounding this pixel, $\breve{g}(x,y)$. A higher value of k results in a higher output pixel value than will

result using lower values of *k* will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Wang, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Wang.

<u>Claim 1</u>

204. Independent claim 1 consists of a preamble and two Gonzalez claim elements: a means for averaging; and a means for selecting and transforming.

205. The preamble of claim 1 reads as follows:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

206. I understand Polaroid's position to be that the preamble should not be considered a element of claim 1. However, I also understand that, in the event the preamble of claim 1 is found to be element of the claim, Polaroid believes that "*continuously enhancing*" should be construed to mean "successively transforming" and that "*electronic information signals*" should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values." See Joint Claim Construction Statement (Corrected).

207. Polaroid also asserts that the term "*electronic image data received in a continuous stream* of *electronic information signals*" that appears in the preamble should be construed as "electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" and that the term "*each signal having a value within a determinate dynamic range of values*" should be construed as "each

signal being associated with a value that lies within a range of possible values bounded by definite limits." (Id.)

208. As construed by Polaroid, the elements of the preamble are taught by each of the Gonzalez algorithm, Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

209. The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.

210. Gonzalez describes a system for enhancing image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a

number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel *(x,y)*. Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

211. Richard describes a system for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

212. Lee describes a system for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As

every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.

213. Sabri describes a system for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.

214. Rangayyan describes a system for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to "0" and all six bits of the value equal to "1." Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an

original image, each luminance value lying within a range of possible values that is bounded by definite limits.

215. Chen describes a system for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

216. Narendra describes a system for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p. 656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

217. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

218. It has been explained to me that, in order to properly interpret a means-plus-function claim element, one must first identify the function that the means is to perform and then one must review the specification to identify a structure, material or act corresponding to the identified function.

219. I understand that Polaroid contends that the function performed by the "means for averaging" is averaging electronic information signals corresponding to selected pluralities of pixels and to provide an average electronic information signal for each of the averaged pluralities of pixels. *See* Joint Claim Construction Statement (Corrected).

220. As above, Polaroid has taken the position that "*averaging*" should be construed to mean "calculating an intermediate value" and that "*average electronic information signal*" should be construed to mean "the signal providing pixel information, such as a color, luminance, or chrominance value of the calculated intermediate value." *See* Joint Claim Construction Statement (Corrected).

221. Polaroid has identified a low-pass filter or a block averager as the structure described in the '381 patent corresponding to this function. *See* Joint Claim Construction Statement (Corrected). That is, I understand Polaroid's position with respect to this claim element to be that the "means for averaging" is a structure that performs a low-pass filtering or block averaging function on a plurality of pixels to produce an intermediate value corresponding to the values of those pixels, or its equivalent.

222. As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). I agree with the above-statement. As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

223. Gonzalez teaches systems that use averages for image enhancement. (Gonzalez, p. 161). In Equation 4.3-1, a formula is provided to calculate the arithmetic mean (average) of a number of pixel values from a selected neighborhood around the pixel being processed, indicated by *S*. Gonzalez teaches that a 3×3 neighborhood including nine pixels could be used, but also that "we are not limited to square neighborhoods". The intermediate calculated value of an average taught by Gonzalez may be implemented in a computing device, such as a software program running on a computer.

224. Richard teaches using a block averaging apparatus consisting of filters that receive a plurality of pixel values and output an intermediate value for those pixels. (see Richard, col. 3, lines 16-56). The means for computing a local mean value is made up of a horizontal-filtering device connected in series to a vertical filtering device. (Richard, col. 3, lines 16-20). The local mean value is an intermediate calculated value. These filtering devices provide a value representing the arithmetic mean of a plurality of pixel values in a window (i.e., a block) centered on the pixel being processed. (Richard, col. 3, lines 19-25). This value represents a value that would be obtained by computing the arithmetic mean of pixel values centered around the pixel value being processed. (Richard, col. 4, lines 49-53). Richard,

therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

225. Lee teaches using a block averager means that receives as input a plurality of pixel values and outputs an intermediate value calculated value for those pixels. (Lee, p. 165, last paragraph to p. 166, first paragraph). Equation 1 on page 166 produces an intermediate calculated value representing the average of these pixels. Lee further teaches that these algorithms are performed on digital computers. (Lee, P. 165, Introduction, line 1-2). As Lee further teaches making his algorithms more computationally efficient, it is evident that the block averager of equation 1 may easily be implemented on a computer. (Lee, P. 165, Introduction, 1st paragraph, last sentence; second paragraph). Therefore, Lee teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

226. Sabri teaches using a block averaging means for receiving as input a plurality of pixel values and outputs an average value (i.e., an intermediate calculated value) for those pixels. (see Sabri, col. 3, lines 35-68). In Sabri, an apparatus has a summing means (Fig. 1 and Fig. 2, element 14) which computes and outputs an average value from received input pixel values. (Sabri, col. 3, lines 38-45). The summing means of Figure 1 serves to compute for a group of pixels a weighted average value according to the identified formula. (Sabri, col. 3, 38-47). This formula computes the sum of each luminance value for a series of successive luminance values in a region defined by column *n* and row *m*. (Id.) Each luminance value in the defined region is multiplied by a fractional weighting coefficient and summed to provide a weighted average value. This weighted average is an intermediate calculated value that is provided for the group of luminance values. Sabri, therefore, teaches a block averager as well as a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

227. Rangayyan describes using a block averager that receives as input a plurality of pixel values and outputs an intermediate calculated value representing an average for those pixels. (see Rangayyan, p. 561, col. 2, Section C, first paragraph). The average *a* is computed using a plurality of pixel values received as input. These plurality of pixels are the neighboring pixels forming a block (i.e., a matrix) centered around the pixel being processed. (Rangayyan, p. 561, col. 1, Section B, first paragraph). Therefore, Rangayyan teaches a block averager that receives as input a plurality of pixels and outputs an intermediate value for those pixels.

228. Chen teaches using a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Chen, col. 5, lines 25-50). The image filtering and enhancing circuit of Chen includes a pixel value averaging means. (Chen, col. 5., lines 25-26; Fig. 1, element 40). This averaging means computes and outputs an intermediate calculated value representing an average for a block of pixel values neighboring the pixel being processed. (Chen, col. 5, lines 35-42). Chen, therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

229. Narendra teaches using a low-pass filter that receives as input a plurality of pixels and outputs an intermediate value for those pixels. (see Narendra, p.657, col. 2, first full paragraph). Narendra teaches implementing the local average function identified in Figure 2 as a low-pass filter ("LPF") as identified in Figure 4. The local average function is computed on a local area surrounding the pixel. (Narendra, p.656, col. 2, first full paragraph). Thus, Narendra, teaches a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixel values.

230. The Gonzalez algorithm operates on the input pixel itself, without taking an average. However, as I observe directly above, using a block average or low-pass filter in the

context of a contrast enhancement was well-known, as taught by any one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen or Narendra. It would have been obvious to include the averages taught by those references in the Gonzalez algorithm to provide for local, rather than global, contrast. (Gonzalez, p. 160).

<u>...means for selecting and transforming....</u>

231. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

232. Polaroid takes the position that the function performed by this means is that of selecting one of a plurality of different transfer functions for each of the succeeding pixels whereby each transfer function is selected as a function of (1) the electronic signal information for one pixel and (2) the average electronic information for the select plurality of pixels containing the pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic

information signals such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value. *See* Joint Claim Construction Statement (Corrected).

233. I understand from the Joint Claim Construction Statement that Polaroid has identified the following formula, and equivalents of the formula, as the structure recited by the '381 patent for performing this function:

$$Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}, \text{ where } \gamma = (1+C)^{(Av/M-1)}$$

where Y_{OUT} is the transformed signal providing pixel information, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range.

234. Therefore, I understand Polaroid's contention to be that the "means for selecting and transforming" is any algorithm that modifies a transformation function, such as $(Y_{MAX}(Y_{IN}/Y_{MAX}))$ using a power, γ, that includes the result of a ratio of a calculated intermediate value (Av) divided by any value within the dynamic range (M).

235. The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, *I*, into an output pixel value *FLEV* as follows:

$$FLEV = FH * \text{EXP}(SS*(GN-I)) + 0.5$$

(Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (*FH/T*) over a value in the range of values because the function SS is computed as follows:

$$SS = (-1/GN) * \text{ALOG}(FH/T)$$

(Gonzalez, p. 454, see computation of variable SS). *GN* represents the maximum value of the intended output device. *GN* therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, *I*, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (*FH/T*) over a value in the range of values (in this case, *GN*).

236. Because Gonzalez algorithm suggests each and every element of claim 1, as it is proposed to be construed by Polaroid, I am of the opinion that claim 1 is invalid, as that concept has been explained to me.

237. Furthermore, as I have described above, each of Richard, Lee, Sabri, Rangayyan, Chen, and Narendra describe image processing systems that use transform functions to transform an input pixel value and that use block averagers (the "means for averaging").

238. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Gonzalez is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Gonzalez reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Gonzalez in combination with the Gonzalez algorithm.

239. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Richard is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Richard reference and the Gonzalez algorithm.

Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Richard in combination with the Gonzalez algorithm.

240. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Lee is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Lee reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Lee in combination with the Gonzalez algorithm.

241. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Sabri is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Sabri reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Sabri in combination with the Gonzalez algorithm.

242. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Chen is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Chen reference and Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of the Chen reference in combination with the Gonzalez algorithm.

243. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Narendra is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Narendra and the Gonzalez algorithm references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Narendra in combination with the Gonzalez algorithm.

244. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

245. Claim 2, therefore, recites a method having all the elements of claim 1 and including the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light or high light condition. Such functions are suggested the combination of the Gonzalez algorithm with any one of Gonzalez, Richard, Rangayyan, Lee, or Narendra.

246. Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, $A(x,y)$.

(Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, *K*, by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq. 4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, *K*, with the mean value of the neighboring pixels so that the gain would increase in areas of low light or high light. Therefore, I believe that claim 8 is obvious in view of Gonzalez.

247. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $|p-a|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C*, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

248. Rangayyan teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing that mean by the dynamic range of the electronic information signals. (Rangayyan, p. 561, Section C. Contrast Enhancement). Rangayyan teaches that the first step in transforming an input pixel value is to calculate a contrast measure, C. The value of C is arrived at by dividing the absolute value of the difference between the input pixel value, p, and the average value, a, of pixels surrounding the input pixel, $|p - a|$, by $(p+ a)$. (Rangayyan, p.561, col. 1, Equation for $C = |p - a|/(p+ a)$. The square root of the contrast factor, C, is calculated, C', and then used in a selected transfer function $p' = a(1+C')/(1-C')$, when $p>=a$ or $p' = a(1-C')/(1+C')$, when $p<a$. A new pixel value is then computed from p' using one of the following equations:

$$p''=255(p'-min)/(max-min); \text{ or}$$

$$p''=255(max-p')/(max-min).$$

The value of *max* represents the maximum pixel value and the value of *min* represents the minimum pixel value; *(max-min)* represents, therefore, the maximum dynamic range of the image. Rangayyan, therefore, teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing the mean by the dynamic range of the electronic information signals.

249. Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph).

"The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee to a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 8 is an obvious extension of Lee.

250. Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, α, with the mean value of the neighboring pixels so that gain would increase in areas of low light or high light. Therefore, I believe claim 8 is obvious in view of Narendra.

251. Because each and every element of claim 2, as it is proposed to be construed by Polaroid, is suggested by the combination of the Gonzalez algorithm with any one of Gonzalez, Richard, Rangayyan, Lee, or Narendra, I am of the opinion that claim 2 is obvious in view of any combination of those references, as that concept has been explained to me.

252. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of

> contrast provided in those areas of higher contrast provided by said select transfer function.

253. Claim 3, therefore, recites a method having all the elements of claim 2 and claim 1, and including the element that the transfer function is selected as a function of a determined constant, the value of which corresponds to the amount of contrast provided in areas of higher contrast. Such functions are suggested by the Gonzalez algorithm in combination with Gonzalez, Richard, Lee, or Narendra.

254. Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function g(x,y) applies a local gain factor A(x,y) to the difference between the pixel value being processed f(x,y) and the local mean m(x,y) of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor A(x,y) amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

255. Richard teaches a system in which a constant value, *K*, can be adjusted by an operator to control the contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Y_{ij} multiplied by (M_v/M_g), and further multiplied by this constant *K*. (Richard, Fig. 1) An increase in *K* will increase the contrast between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the

lightest areas of an image and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

256. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a higher output pixel value than a lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

257. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by mulitplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Narendra.

258. Because each and every element of claim 3, as it is proposed to be construed by Polaroid, is suggested the combination of the Gonzalez algorithm and anyone of Gonzalez, Richard, Lee, Narendra, or Wang. I am of the opinion that claim 3 is obvious in view of any combination of those references.

V. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION USING CLAIM CONSTRUCTION PROPOSED BY HP

259. I have also been asked to assess the novelty and obviousness of claims 1-3 and 7-9 assuming that the Court adopts HP's proposed claim constructions. I believe that claims 7-9 of the '381 patent are an obvious extension of Richard[11] and that claim 7 is an obvious extension of Sabri.[12] With respect to claims 1-3, I believe they are an obvious extension of Rangayyan[13] and that claim 1 is an obvious extension of Sabri. Again, I first assess claim 7, which is a method claim with a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

<u>A method for continuously enhancing....</u>

260. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

261. I understand HP's position to be that *"continuously enhancing"* should be construed to mean "successively transforming" and that *"electronic information signals"* should

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[11] A chart identifying how Richard suggests each and every element of claims 7-9 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix K.

[12] A chart identifying how Sabri suggests each and every element of claims 1 and 7 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix L.

[13] A chart identifying how Rangayyan suggests each and every element of claims 1-3 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix M.

be construed to mean "signals providing luminance pixel information." See Joint Claim Construction Statement (Corrected).

262. HP also states that the phrase *"electronic image data received in a continuous stream of electronic information signals"* that appears in the preamble should be construed as "an uninterrupted stream of received luminance image data defining an original image to be recorded" and that the phrase *"each signal having a value within a determinate dynamic range of values"* should be construed as "each signal ha[ving] an associated luminance value that lies within a predetermined group of luminance values." (Id.)

263. As construed by HP, the elements of the preamble are taught or suggested by Richard and Sabri.

264. Richard teaches methods for receiving and continuously enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Richard teaches that a sequence of numerical pixel values representing luminance are received. (Richard, col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will lie within a predetermined group of luminance values. Richard further teaches that the system has an output terminal for delivering a sequence of numerical pixel values of luminance having enhanced contrast. (Richard, col. 2, ll. 24-25). The output values produced by Richard could be sent to a computing device for storage on, for example, a disk drive. Therefore, Richard teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that may be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express the luminance value.

265. Sabri teaches systems and methods for continuously enhancing the quality of video image data originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

<u>…averaging the electronic information signals…</u>

266. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

267. I understand that HP contends that "*averaging*" should be construed as "an arithmetic mean" and that "*average electronic information signal*", to the extent it needs to be construed, to mean "the average of the electronic information signals." *See* Joint Claim Construction Statement (Corrected).

268. As construed by HP, this step reads as calculating the arithmetic mean for a selected group of pixels. In connection with my analysis above of claim 7 using Polaroid's

construction, I observed that averaging electronic information signals, for example, by using low-pass filtering and block averaging techniques, was well-known and disclosed by at least each of Richard and Sabri. Even Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25). I agree with this statement.

...selecting one of a plurality of different transfer functions.....

269. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

270. I understand that HP construes this step to mean that "each input pixel has an associated transfer function out of different transfer functions and the transfer function is selected based on the input pixel value, and the average that was formed using the input pixel value, where each input pixel is part of only one average". *See* Joint Claim Construction Statement (Corrected). Selecting a transfer function using an average is taught by Richard and Sabri but those references teach that a pixel can be part of multiple averages (that is, they teach use of a "moving block averager"). However, block averagers that calculate a single average for a group of pixels (known as "non-overlapping, block-by-block averagers") are a type of block averagers that is well-known. See, e.g, "Progressive Refinement of Raster Images," by Kenneth R. Sloan, Jr. and Steven L. Tanimoto, (IEEE Transactions on Computers, Vol. C-28, No. 11, November 1979) ("Sloan"). Therefore, I believe replacing a moving block averager with a non-

overlapping, block-by-block averager would be an obvious extension of the Richard and Sabri references.

271. Richard teaches that each input pixel has a transfer function selected based on its pixel value and the average of local mean, M_v, which includes the input pixel value. Richard teaches "means for multiplying the value of luminance of the point being processed by a variable coefficient which is proportional to the *ratio* M_v/M_g" (Richard, col. 1, lines 66-68). M_v is an average of luminance values of points which are adjacent to, and include, the pixel being processed for contrast enhancement. (Richard, col. 2, lines 19-22). Richard teaches that an input pixel value is transformed according to the following function: $Y_{ij}(M_v/M_g)*K$ The transfer function in Richard is, therefore, dependent on the input pixel value, Y_{ij}, and the average value of neighboring pixels (including the input pixel value), M_v. Although Richard does not explicitly teach a non-overlapping, block-by-block averager, I believe it would have been obvious to try to use such an averager to calculate the local mean value, M_v, in the Richard system because it would provide a local mean value and, among other reasons, would result in lower computational load on a system because only a single average value is calculated for each group of pixels.

272. Sabri teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel. (Sabri, col. 2, lines 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value itself, C_{ij}. (Sabri, col. 2, lines 29-39). The contrast enhancement factor is then added to a calculation that includes the average, φ, of the values of the pixel and the pixels preceding the pixel being processed. (Sabri, col. 2, lines 40-46). Sabri, therefore, teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel. Although Sabri does not explicitly teach a non-overlapping, block-by-block averager, I believe it would have been

obvious to try to use such an averager to calculate the local mean value, M_v, in the Sabri system because it would provide a local mean value and, among other reasons, would result in lower computational load on a system because only a single average value is calculated for each group of pixels.

<u>….transforming the electronic information signal….</u>

273. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

274. HP provides the following definition for the transformation step:

> each input pixel that has been part of the averaging step is altered based on the corresponding average electronic information signal to which it is associated and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing a select proportionate value of the dynamic range of the average electronic information signals. *See* Joint Claim Construction Statement (Corrected).

275. As construed by HP, such functions are taught by each of Richard and Sabri.

276. Richard teaches altering an input signal using the pixel value itself, an arithmetic mean of the value of a group of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean associated with the pixel group by an integer value within a range of values that represent the dynamic range. The transformation function depicted as element 5 in Figure 1 of Richard alters an input signal by multiplying the value of the pixel, Y_{ij}, by the ratio of the local mean value of nearby pixels, M_v, to the global mean value of the image, M_g, and further multiplies that by a constant K. (Richard, Figure 1, elements 10-14). As taught by Richard, therefore, a pixel's value is altered based on the starting value of the pixel, Y_{ij}, and based on the result of dividing the local average, M_v, by a select proportionate value of the

dynamic range, M_g. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Further, because $1/M_g$ is the output of a ROM memory element, M_g may only take on a finite number of digital values. Richards teaches a represented by a finite number of bits. (*See,* e.g., FIG. 1 of Richard in which M_g is the output of a ROM memory element). Richard, therefore, teaches altering an input signal using the pixel value itself, an arithmetic mean of a group of values of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean of a group of values of pixels associated with the pixel by a value within a range of values that represent the dynamic range.

277. Sabri teaches altering an input signal using the pixel value, the calculated arithmetic mean for the group of pixels neighboring including the subject pixel (?) and is based on the result of dividing the calculated arithmetic mean by an integer value within a range of values that represent the dynamic range. (Sabri, Fig. 1). The value of the transformation function B_{ij} is computed from an average referred to as ϕ and a contrast enhancement factor referred to as γ_{ij}. (Sabri, col. 2, lines 40-46). The contrast enhancement signal is derived from the input video signal, C_{ij}. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, φ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, ϕ, is divided by the maximum range, R, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches altering an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that calculated arithmetic mean by an integer value within a range of values that represent the dynamic range.

278. Because each and every element of claim 7, except for use of a non-overlapping, block-by-block averager, is found in each of Richard and Sabri, and because I believe that use of a non-overlapping, block-by-block averager is an obvious extension to the subject matter of claim 7, I am of the opinion that claim 7, as proposed to be construed by HP, is obvious, as that concept has been explained to me, when compared to either reference. For the same reason, claim 7 would be anticipated by each of Richard and Sabri if a non-overlapping block by block although were not a claim requirement.

Claim 8

279. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

280. Claim 8, therefore, requires a method having all the elements of claim 7 and the additional element that the transfer function is selected to provide higher contrast to pixels when the calculated arithmetic mean indicates a low light or high light condition. Such functions are taught by Richard.

281. Richard teaches selecting a transfer function to provide higher contrast for a pixel when the calculated arithmetic mean represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as

a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of Mv/Mg will be very close to 0 (for very dark pixels) and will be greater than one for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for the darkest pixels as compared to less dark pixels and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for the lighter pixels as compared to less light pixels. Richard, therefore, teaches selecting the transfer function to provide higher contrast within the dark and light regions of an image.

282. I, therefore, believe that claim 8, as proposed to be construed by HP, is an obvious extension of Richard.

283. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

284. Claim 9, therefore, recites a method having all the elements of claim 8 and claim 7, and the additional element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

285. Richard teaches a system in which a constant value, *K*, can be determined by an operator to increase the contrast in areas of higher contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Y_{ij} multiplied by (M_v/M_g), and further multiplied by this

constant *K*. (Richard, Fig. 1) An increase in *K* will increase the contrast between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the lightest areas of an image and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

286. Therefore, I am of the opinion that claim 9, as it is proposed to be construed by HP, is an obvious extension of Richard.

<u>Claim 1</u>

287. Independent claim 1 consists of a preamble and two Gonzalez claim elements : a means for averaging; and a means for selecting and transforming.

288. The preamble of claim 1 reads as follows:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

289. I understand HP's position to be that "*continuously enhancing*" should be construed to mean "successively transforming" and that "*electronic information signals*" should be construed to mean "signals providing luminance pixel information." See Joint Claim Construction Statement (Corrected).

290. HP also states that the term "*electronic image data received in a continuous stream of electronic information signals*" that appears in the preamble should be construed as "an uninterrupted stream of received luminance image data defining an original image to be recorded" and that the term "*each signal having a value within a determinate dynamic range of*

values" should be construed as "each signal has an associated luminance value that lies within a predetermined group of luminance values." (Id.)

291. As construed by HP, each of the elements of the preamble are taught by each of Sabri and Rangayyan.

292. Sabri teaches systems and methods for enhancing the quality of video images, which are electronic image data, originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

293. Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels received via acquisition devices, the pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Since each pixel value in Rangayyan is a number expressed as six bits, every pixel value will lie within a predetermined group of luminance values. Therefore, Rangayyan teaches successive transformation of an uninterrupted stream of received

luminance image data defining an original image that could be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

<u>...means for averaging...</u>

294. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

295. It has been explained to me that, in order to properly interpret a "means-plus-function" claim element, one must first identify the function that the means is to perform and then one must review the specification to identify a structure, material or act corresponding to that function.

296. I understand that HP states that the function performed by the "means for averaging" is providing an average for selected pixel values around one pixel, where the average is correlated to each pixel making up the average. *See* Joint Claim Construction Statement (Corrected). HP has identified a block averager with a buffer memory that takes luminance values as an input and outputs an average luminance value that is correlated to each pixel in the block, and equivalents of that structure. *See* Joint Claim Construction Statement (Corrected).

297. In connection with my analysis above of claim 7 using Polaroid's construction, I discussed that averaging electronic information signals, for example, by using low-pass filtering and block averaging techniques are well-known and are taught by at least, Sabri or Rangayyan.

298. Further to the Sabri and Rangayyan references, it would be natural to use one or more buffer memories as in HP's construction. For example, many of these references execute

an averager or low-pass filter on a computing device. The computing device would use one or buffers in memory for storing any input value, intermediate calculated values or output values in performing the averaging.

<u>...means for selecting and transforming...</u>

299. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

300. HP states that function performed by this means is that of selecting a transfer function for each incoming pixel based on the pixel value and the average electronic information signal values of a group of pixels that includes the subject pixel, and based on the result of dividing a first existing data value representing the average electronic information signal of the group of pixels by a second existing data value representing the dynamic range of the average electronic information signals. *See* Joint Claim Construction Statement (Corrected).

301. I understand from the Joint Claim Construction Statement that HP has identified the circuitry in Fig. 4 of the '381 patent as the structure corresponding to this function which computes the following function:

$$Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}, \text{ where } \gamma = (1+C)^{(Av/M-1)}$$

where Y_{OUT} is the transformed signal providing pixel information, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, C is a chosen number, Av is the average electronic information signal of a corresponding group of pixels, and M is the dynamic range of the electronic information signals.

302. I have not found any references that explicitly disclose the circuit described in Fig. 4 of the '381 patent. However, I understand that Polaroid may take the position that any computer implementing the algorithm set forth in paragraph 319, above, is an infringing structure. If that is determined to be the case, then each of Sabri and Rangayyan teach the element of selecting and transforming the input.

303. Sabri teaches selecting a transfer function using the pixel value itself and the calculated arithmetic mean for the group of pixels that includes and neighbors the subject pixel and also based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals. (Sabri, Fig. 1). The value of the transformation function B_{ij} is computed from an average referred to as ϕ and a contrast enhancement factor referred to as γ_{ij}. (Sabri, col. 2, lines 40-46). The contrast enhancement factor is derived from the input video signal, C_{ij}. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, ϕ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, ϕ, is divided by the maximum range, R, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches using a function that transforms an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that mean by the dynamic range of a value equal to the electronic information signals.

304. Rangayyan teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing that mean by a value equal to the dynamic range of the electronic information signals. (Rangayyan, p. 561, Section C. Contrast Enhancement). Rangayyan teaches that the first step in transforming an input pixel value is to calculate a contrast measure, *C*. The value of *C* is arrived at by dividing the absolute value of the difference between the input pixel value, *p*, and the average value, *a*, of pixels surrounding the input pixel, $|p - a|$, by $(p+ a)$. (Rangayyan, p.561, col. 1, Equation for $C = |p - a|/(p+ a)$). The square root of the contrast factor, *C*, is calculated, C', and then used in a selected transfer function $p' = a(1+C')/(1-C')$, when $p>=a$ or $p' = a(1-C')/(1+C')$, when $p<a$. A new pixel value is then computed from *p'* using one of the following equations:

$$p''=255(p'-min)/(max-min); \text{ or}$$

$$p''=255(max-p')/(max-min).$$

The value of *max* represents the maximum pixel value and the value of *min* represents the minimum pixel value; *(max-min)* represents, therefore, the maximum dynamic range of the image. Rangayyan, therefore, teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals.

305. Because each and every element of claim 1, as it is proposed to be construed by HP, is suggested by Sabri or Rangayyan, I am of the opinion that claim 1 is invalid, as that concept has been explained to me.

306. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

307. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $|p\text{-}a|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C*, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

308. Claim 2, therefore, recites a method having all the elements of claim 1 and the additional element that the transfer function is selected to provide higher contrast to pixels when

an average value indicates a low light or high light condition. Such functions are taught by Rangayyan.

309. Because Rangayyan suggests each and every element of claim 2, I am of the opinion that claim 2, as it is proposed to be construed by HP, is an obvious extension of Rangayyan.

310. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.

311. Claim 3, therefore, recites a method having all the elements of claim 2 and claim 1, and the additional element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. In effect, claim 3 is directed to a "gain factor" that can be used to increase contrast between pixels.

312. Gain factors are well-known in the art, see, e.g., Gonzalez, Richard, Lee, Sabri, Narendra and Wang. Gonzalez teaches that the transfer function is computed with a determined constant *k*, which is determined to be a value in the range between 0 and 1 and which controls the gain. (Gonzalez, p. 160, Equation (4.2-15)). Richard teaches a system in which a constant value, *K*, can be determined by an operator to control the contrast applied to an image. (Richard, col. 5, lines 55-58). Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$ plus the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a determined gain factor, *k*. *k*, therefore, controls the gain. (Lee, p.166, col. 1, Eq. 4). Chen teaches using a constant *k* for adjusting the contrast calculated by the selected transfer function.

(Chen, col. 1, lines 22-49). Sabri teaches using determined constants to control contrast enhancement. (Sabri, col. 2, lines 29-39). Narendra teaches a transfer function using a locally adaptive gain factor based on a determined constant. The constant, threefore, controls the gain. (Narendra, p. 656, col. 2., Equation (1)). Wang teaches using the contrast gain factor of a determined constant *k*. (Wang, p. 376, Equation (6-4)). I believe that one of ordinary skill in the art would have found it obvious to modify the techniques of Rangayyan to try to use a gain factor, as described by any one of the references above, to increase contrast in a processed image.

VI. CONCLUSION

It is my opinion that the subject matter of claims 1-3 and 7-9 of the '381 patent lack novelty or are otherwise obvious in view of the disclosures of the above-identified prior art references.

Rangaraj Rangayyan, Ph.D.

Exhibit 4 (cont.)

APPENDIX A

Raj RANGAYYAN, PhD, PEng, FIEEE, FEIC, FAIMBE, FSPIE, FSIIM, FCMBES

EXECUTIVE SUMMARY OF CV

CURRENT POSITIONS: "University Professor"; Professor, Department of Electrical and Computer Engineering; Adjunct Professor, Departments of Surgery and Radiology, University of Calgary.

RESEARCH: Dr. Rangayyan has developed several algorithms for biomedical signal and image processing applications, including analysis of mammograms for computer-aided diagnosis of breast cancer, analysis of collagen alignment and fine vascular anatomy to study ligament healing and treatment, high-resolution image data compression for digital teleradiology, and computer-aided diagnosis of cartilage pathology via the analysis of knee-joint vibration signals. He has 120 journal papers and 200 conference publications to his credit, and has completed the supervision of 19 Master's and 11 Doctoral theses. His research has been featured in many newsletters, magazines, and newspapers, as well as in several radio and television interviews.

Methods, datasets, and software developed by Dr. Rangayyan have been used by researchers in Canada, the U.S.A., U.K., Brazil, Argentina, Malaysia, Spain, France, Romania, and China. He has brought to the University of Calgary more than 25 international visiting researchers. He is collaborating (or has collaborated) with research groups not only in Calgary, Alberta, and Canada, but also in Brazil, China, France, Spain, Romania, Malaysia, the U.S., and the U.K.

TEACHING: ENGG 213- Engineering Computation; ENGG 215- Engineering Practice, Design, and Communication; ENGG 233- Computing for Engineers I; ENGG 303- Electrical Circuits and Machines; ENGG 323- Systems and Instrumentation; ENGG 327- Engineering Computation; ENGG 333- Computing for Engineers II; ENEL 327- Signals and Systems; ENEL 563- Biomedical Signal Analysis; ENEL 593- Digital Filters; ENEL 599- Electrical Engineering Project; ENEL 697- Digital Image Processing.

Dr. Rangayyan is the author of two books: "Biomedical Signal Analysis" (IEEE Press and Wiley, New York, NY, 516 pages, 2002); and "Biomedical Image Analysis" (1306 pages, CRC Press, Boca Raton, FL, 2005).

Dr. Rangayyan has lectured in more than 20 countries. He has held Visiting Professorships with the University of Liverpool, Liverpool, UK; Tampere University of Technology, Tampere, Finland; Universitatea Politehnica Bucureşti, Bucharest, Romania; Universidade de São Paulo, São Paulo, Brasil; Cleveland Clinic Foundation, Cleveland, OH; Indian Institute of Science, Bangalore, India; Manipal Institute of Technology, Manipal, India; Beijing University of Posts and Telecommunications, Beijing, China; and École Nationale Supérieure des Télécommunications de Bretagne, Brest, France.

AWARDS AND RECOGNITION: ***Fellow***, CMBES (2007); ***Fellow***, SIIM (2007); ***Fellow***, SPIE (2003); ***Fellow***, AIMBE (2003); ***Fellow***, EIC (2002); ***Fellow***, IEEE (2001); IEEE Third Millennium Medal (2000); Killam Resident Fellowship (1999, 2002, 2007); Research Excellence Awards of the Department of Electrical and Computer Engineering (1997 and 2001); Research Excellence Award of the Faculty of Engineering (1997); Outstanding Service Award of the India-Canada Association of Calgary (1997); Excellence in Professional Field Award of the India-Canada Association of Calgary (2002).

INTERACTION WITH INDUSTRY: Fischer Imaging, VitalSines, Imaging Dynamics Corporation, Medipattern Corporation, VTA Photogrammetrics Consultants Ltd., ITT Export Corporation, Tectran Research Inc., and Hycal Energy Research Laboratories Ltd. Techniques for computer-aided diagnosis of breast cancer and knee-joint cartilage pathology have been licensed to University Technologies International Inc. Dr. Rangayyan has worked with Calgary Technologies Inc. and Mind to Market

Solutions Inc. on the market feasibility of some of his methods, and holds a patent on methods for auditory display of knee-joint vibration signals.

SERVICE AND LEADERSHIP: Associate Vice-President (Research) (2000-2002). Acting Head (1991-92) and Associate Head for Undergraduate Studies (1993-94), Department of Electrical and Computer Engineering. Associate Editor, IEEE Transactions on Biomedical Engineering (1989-96). Program Chair, 15th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS), San Diego, CA, 1993. Program Co-Chair, 20th Annual International Conference of the IEEE EMBS, Hong Kong, 1998. Co-Chair and Co-Editor, IASTED International Conference on Telehealth, Banff, AB, 2005.

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Education:

Ph.D., Electrical Engineering, Indian Institute of Science, Bangalore, India (1980).

Bachelor of Engineering (B.E.), Electronics and Communication, University of Mysore, India (1976).

Positions Held:

"University Professor", University of Calgary (2003-present).

Associate Vice-President (Research) (2000-2002).

Professor, Department of Electrical and Computer Engineering (1989-present).

Adjunct Professor, Departments of Surgery and Radiology (1992-present).

Fellow, Latin American Research Centre (2006-present).

Associate Head (Undergraduate Studies), Department of Electrical and Computer Engineering (1993-94).

Acting Head, Department of Electrical and Computer Engineering (1991-92).

(Please see Sections L and T for Institutions Visited and Visiting Appointments held.)

Associate Professor, Department of Electrical Engineering, University of Calgary (1984-89).

Assistant Professor, Department of Electrical Engineering, University of Manitoba, Winnipeg, Canada (1982-84).

Systems Analyst, Department of Pathology, University of Manitoba, Winnipeg, Canada (1981-82).

Project Assistant, School of Automation, Indian Institute of Science, Bangalore, India (1980-81).

Registered Professional Engineer in the Province of Alberta, Canada, (1986-present).

Professional Interests:

Research and teaching in the areas Biomedical Engineering, Digital Signal Processing, Digital Image Processing, Signals and Systems, Biomedical Signal and Image Analysis, Computer Vision, Pattern Recognition, Medical Imaging, and Computer-aided diagnosis.

Other Interests:

Classical Music of India, Flute, Percussion, New-age Music, Fusion Music, Photography.

A. Papers in Refereed Journals

Note: The numbering of entries in each category starts with the first such item in my career. The number of the first entry is thus my career total in each category. The names of my research students/ trainees are underlined.

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A1. Works-in-Progress (Papers Submitted to Journals/ in Preparation/ being Revised)

9. P.M. de Azevedo-Marques, N.A. Rosa, A.J.M. Traina, C. Traina Junior, S.K. Kinoshita, and R.M. Rangayyan, "Reducing the Semantic Gap in Content-based Image Retrieval in Mammography with Relevance Feedback and Inclusion of Expert Knowledge".

8. Y.F. Wu, R.M. Rangayyan, Y. Zhou, and S.C. Ng, "Filtering electrocardiographic signals using an unbiased and normalized adaptive noise reduction system".

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4. C. Serrano, B. Acha, and R.M. Rangayyan, "Detection of microcalcifications in mammograms using error of prediction and statistical measures".

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B. Abstracts and Letters in Journals

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D. Books Edited/ Conference Proceedings Edited/ Journal Issues Edited

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F. Papers in Refereed Conference Proceedings

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G. Communications (lectures, displays, abstracts) at Conferences

38. R.M. Rangayyan, invited talk and panel discussion on "Education in Biomedical Engineering: crossing professional and national boundries", 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, August 2007, Lyon, France.

37. R.M. Rangayyan, Keynote address on "Computer-aided detection of signs of early breast cancer", at the Third IEE International Seminar on Medical Applications of Signal Processing, London, UK, 3 – 4 November 2005.

36. R.M. Rangayyan, F.J. Ayres, and J.E.L. Desautels, "Computer-aided diagnosis of early breast cancer: Detection of signs of architectural distortion", Invited talk and abstract in program booklet, Workshop on Alternatives to Mammography, Copenhagen, Denmark, September, 2005.

35. R.M. Rangayyan, F.J. Ayres, and J.E.L. Desautels, "Computer-aided diagnosis of breast cancer: Toward the detection of early and subtle signs", The First World Experts' Congress on Women's Health Medicine and Healthcare, World Academy of Biomedical Technologies, Paris, France, 14 pages, Invited talk, March 2005.

34. R.M. Rangayyan, H. Alto, N.R. Mudigonda, and J.E.L. Desautels, "Content-based retrieval and analysis of breast masses in mammograms", one-page summary on CDROM, paper no. 1170, World Congress on Medical Physics and Biomedical Engineering, Sydney, Australia, August 2003.

33. R.M. Rangayyan, "Computer-aided diagnosis of breast cancer", XIII Brazilian Symposium on Computer Graphics and Image Processing, Gramado, Rio Grande do Sul, Brazil, October, 2000.

32. R.M. Rangayyan, "Computer-aided diagnosis of breast cancer", Congresso Brasileiro de Engenharia Biomédica, Florianôpolis, Santa Catarina, Brazil, September, 2000.

31. N.R. Mudigonda, R.M. Rangayyan, J.E.L. Desautels, and O. Menut, "Segmentation of breast masses in mammograms: A multi-resolution and hierarchical density propagation approach", Proc. 13th Annual International Conference and Exhibition on Computer-assisted Radiology and Surgery, Paris, France, 23-26 June 1999, p 1014.

30. R.M. Rangayyan, "High-performance computing for computer-aided diagnosis of breast cancer", High-performance Computing Symposium, Kingston, ON, June 1999.

29. R.M. Rangayyan and N.R. Mudigonda, "Perception-based measures for computer-aided analysis of mammograms", Proc. Eighth Far West Image Perception Conference, Morley, AB, May 1999, p 4.

28. R.M. Rangayyan, Presentation on "Computer-aided diagnosis of breast cancer", opening ceremony of the Multimedia Advanced Computational Infrastructure (MACI) facility at the Rozsa Centre, University of Calgary, 28 September 1998.

27. R.M. Rangayyan, Member of Panel Discussion on "Info Era", Fenasoft, São Paulo, Brazil, 21 July 1998.

26. R.M. Rangayyan, N.M. El-Faramawy, J.E.L. Desautels, and O.A. Alim, 1997, "Measures of acutance and shape for classification of breast tumors", Shape Modeling International '97, Aizu-Wakamatsu, Japan, 3-6 March 1997.

25. C.B. Frank, Y.T. Zhang, G.D. Bell, K.O. Ladly, and R.M. Rangayyan, 1994, "Effects of joint angular velocity on vibroarthrographic signals in evaluation of knee function and pathology", abstract PS05-1.15, p128, ibid (24).

24. Y.T. Zhang, Y.P. Shen, C.B. Frank, G.D. Bell, K.O. Ladly, and R.M. Rangayyan, 1994, "Modeling of vibroarthrographic transfer function for the knee joint system: A cadaver study", abstract PS05-1.8, p124, World Congress on Medical Physics and Biomedical Engineering, 21-26 August 1994, Rio de Janiero, Brazil.

23. R.M. Rangayyan, C.B. Frank, Y.T. Zhang, and K.O. Ladly, Exhibit on Knee Sounds for the Sport Science Exhibits at the Edmonton Space and Science Centre, presented in March 1994.

22. D. Boulfelfel, R.M. Rangayyan, L.J. Hahn, and R. Kloiber, 1993, "Three-dimensional restoration of single photon emission computed tomography images using a Kalman-Metz filter", CT'93, International Symposium on Computerized Tomography, Novosibirsk, Russia, 10-14 August 1993, p33.

21. L. Shen, R.M. Rangayyan, and J.E.L. Desautels, 1993, "Computer detection and analysis of mammographic calcifications", presented at the Biennial Meeting of the International Association for Breast Cancer Research, April 1993, Banff, Alberta.

20. L. Shen, R.M. Rangayyan, and J.E.L. Desautels, 1992, "Shape analysis of mammographic calcifications", 55th Annual Scientific Meeting of the Canadian Association of Radiologists, Halifax, 21-25 June 1992, p.88.

19. R.M. Rangayyan, "Region-based enhancement and analysis of mammograms", lecture presented at the 13th Ann. Intl. Conf. IEEE Engineering in Medicine and Biology Society, Orlando, Florida, USA, Oct. 1991.

18. Y.T. Zhang, C.B. Frank, R.M. Rangayyan, G.D. Bell, and K.O. Ladly, "Step size optimization of nonstationary adaptive filtering for knee sound signal analysis", Proc. World Congress on Medical Physics and Biomedical Engineering, Kyoto, Japan 7-12, July 1991, (Medical and Biological Engineering and Computing, Vol. 29, Supplement 1991), p 836.

17. K. Eng, R.M. Rangayyan, P. Veale, R.C. Bray, C.B. Frank, and L. Anscomb, "Image processing techniques for analysis of the vascular structure of ligaments" Proc. World Congress on Medical Physics and Biomedical Engineering, Kyoto, Japan, July 1991, (Medical & Biological Engineering & Computing, Vol. 29, Suppl. 1991), p 836.

16. R.C. Bray, P. Veale, K. Eng, R. Rangayyan, C. Frank, "Quantitative analysis of ligament vascularity by image analysis", The Canadian Orthopaedic Association and The Canadian Orthopaedic Research Society Annual Meeting, Calgary, 2-6 June 1991, p25:20.

15. W.M. Morrow, R. Paranjape, R.M. Rangayyan, and J.E.L. Desautels, "Region-based image processing with applications in mammography", Annual Meeting - Canadian Association of Radiologists, Hamilton, June 1991.

14. R.M. Rangayyan, two invited seminars: "A tutorial on computed tomography", and "Image processing techniques for quantitative analysis of ligament healing and treatment procedures" at the conference "Jornada EPUSP/IEEE em Computação Visual", University of São Paulo, São Paulo, Brazil, 4-7 December, 1990.

13. Y.T. Zhang, K.O Ladly, S. Tavathia, C.B. Frank, R.M. Rangayyan, and G.D. Bell, Display on "Knee Sound Analysis" at the "University of Calgary Science and Technology Week", Health Sciences Centre, Calgary, 20 October 1990.

12. Y.T. Zhang, K.O Ladly, S. Tavathia, C.B. Frank, R.M. Rangayyan, and G.D. Bell, Display on "Joint Sounds" at "Chautauqua: The Science Circuit", Science Alberta Foundation, Calgary, 12-13 October 1990.

11. R.M. Rangayyan, "Introduction", IEEE Western Canada Conference and Exhibition on Telecommunication for Health Care: Telemetry, Teleradiology, and Telemedicine, July 6-7, 1990, Calgary, Canada, Proc. SPIE Vol. 1355, p vi.

10. R.M. Rangayyan, Attendee (by invitation), Franco-Canadian Colloquium on "Telecommunications, Optoelectronics, Image and Signal Processing", organized by the Conference des Grandes Ecoles (France) and the National Committee of Deans of Engineering and Applied Sciences (Canada), Montpellier, France, 10-15 December 1989.

9. R.M. Rangayyan, invited talk on "Approaches to teleradiology in Alberta", and participated in a panel discussion at "Executive Symposium on Telehealth", University of Victoria, 7 November 1989.

8. R.M. Rangayyan, "Digital image processing techniques for quantitative analysis of ligament healing and treatment methods", Electronic Imaging West '89, Pasadena, 10-13 April 1989.

7. R.M. Rangayyan, "Restoration of Nuclear Medicine Images", "Digital Image Processing - A Tutorial" and "Computed Tomography - A Tutorial", Symposium and Workshop on Advances in Imaging and Image Processing, B.A.R.C., Bombay, India, December, 1988.

6. A.P. Dhawan, R. Gordon and R.M. Rangayyan, 1984, "Image restoration in limited-view computed tomography", 70th Scientific Assembly of the Radiological Society of North America, November 25-30, 1984, Washington, D.C.

5. R.M. Rangayyan, 1984, "Tutorial on iterative and object-dependent algorithms for limited-view computed tomography", Optical Society of America. Topical meeting on "Industrial Applications of computed Tomography and NMR Imaging", Hecla Island, Manitoba.

4. R. Gordon and R.M. Rangayyan, 1982, "Computed tomography for remote areas via digital teleradiology", Proc. of 45th Annual Meeting of Canadian Assoc. of Radiologists, Winnipeg, p. 179.

3. R.M. Rangayyan and R. Gordon, 1982, "Expanding the dynamic range of x-ray video-densitometry for digital mammography and teleradiology", ibid.(4), p. 189.

2. R.M. Rangayyan (M.R. Rangaraj) and I.S.N. Murthy, 1980, "On the use of signal length criterion for quantification of PCG signal features", MATSCIENCE Conference, Mysore, March.

1. I.S.N. Murthy and R.M. Rangayyan (M.R. Rangaraj), 1979, "Extraction of action potential from surface EMG", ICS-79 Salzburg, Austria, September.

H. Other Publications

6. Z.Q. Liu, R.M. Rangayyan, and C.B. Frank, 1990, "Linear pattern analysis using scale-space techniques", ibid. (7), pp 4-7.

5. D. Boulfelfel, R.M. Rangayyan, J.A.R. Blais, and L.J. Hahn, 1990, "Nuclear medicine image processing", The Big Byte, University of Calgary, vol. 23, no. 5, November, 1990, pp 8-10.

4. G.R. Kuduvalli and R.M. Rangayyan, 1990, "Linear predictive coding techniques for reversible compression of medical images", ibid. (5), pp 12-15.

3. W.M. Morrow and R.M. Rangayyan, 1990, "High-resolution image processing on the Myrias SPS-2", The Big Byte, University of Calgary, vol. 23, no. 4, July 1990, pp 9-11.

2. R.M. Rangayyan, 1988, "An introduction to Indian classical music," Canadian Music Educator, Vol. 29, No. 4, October 1988, pp. 27-33.

1. S. Chaudhuri, R.M. Rangayyan, S. Walsh, and C. Frank, 1987, "The Role of the Supercomputer in Image Processing: Quantitative Analysis of Collagen Alignment in Ligaments", Super*C, Super Computing Services, University of Calgary, pp. 4-9 (invited feature article).

I. Research Reports

6. T. Strecker, R. Rangayyan and L.E. Turner, 1985, "A digital image acquisition and processing system", Report #25 CO TSRRLT 1985, Department of Electrical Engineering, University of Calgary.

5. R. Gordon, R.M. Rangayyan and D.W. MacEwan, 1982, "Digital mammography for the National breast screening study", Progress Report submitted to the Manitoba Medical Services Foundation, August.

4. V.V.S. Sarma and R.M. Rangayyan (M.R. Rangaraj), 1980, "Pattern classification techniques for speech decryption", Research Report for DRDO project "SPAN", School of Automation, Indian Institute of Science, Bangalore, October.

3. V.V.S. Sarma and R.M. Rangayyan (M.R. Rangaraj), 1980, "Speech analysis and synthesis by linear prediction: A state-of-the-art report", Research Report for DRDO project "SPAN", School of Automation, Indian Institute of Science, Bangalore, April.

2. I.S.N. Murthy and R.M. Rangayyan (M.R. Rangaraj), 1978, "New concepts for PVC detection" and "New techniques for PCG analysis", Department of Electrical Engineering, Indian Institute of Science, Bangalore, September.

1. I.S.N. Murthy, R.M. Rangayyan (M.R. Rangaraj), K.J. Udupa, A.K. Goyal and K.S. Prabhu, "Biosignal processing techniques and hardware", Research Report and Documentation Manual on "Homomorphic analysis and modelling of ECG signals", Dept. of Electrical Engineering, Indian Institute of Science, Bangalore, India, July 1977.

J. Awards and Distinction

24. Killam Resident Fellowship, University of Calgary, 2007.

23. Fellow, Canadian Medical and Biological Engineering Society, 2007.

22. Fellow, Society for Imaging Informatics in Medicine, 2007.

21. "University Professor", University of Calgary (2003 – present).

20. Fellow of SPIE: International Society for Optical Engineering, 2003.

19. Fellow of AIMBE: American Institute for Medical and Biological Engineering, 2003.

18. Killam Resident Fellowship, University of Calgary, 2002.

17. Excellence in Professional Field Award, India-Canada Association of Calgary, 2002.

16. Fellow of EIC: Engineering Institute of Canada, 2002.

15. Research Excellence Award, Department of Electrical and Computer Engineering, University of Calgary, 2001.

14. Fellow of IEEE: Institute of Electrical and Electronics Engineers, 2001.

13. IEEE Third Millennium Medal, 2000.

12. Killam Resident Fellowship, University of Calgary, 1998.

11. Research Excellence Award, Department of Electrical and Computer Engineering, University of Calgary, 1997.

10. Research Excellence Award, Faculty of Engineering, University of Calgary, 1997.

9. Outstanding Service Award, India-Canada Association of Calgary, 1997.

8. Promoted to Senior Member grade in IEEE, 1983.

7. First prize in All India Student paper contest conducted by IEEE India Council, Bombay, February 1979.

6. First prize in Student paper contest conducted by IEEE Bangalore Section, February 1979.

5. Third prize in All India Student paper contest conducted by IEEE India Council, Madras, February 1978.

4. Second prize in Student paper contest conducted by IEEE Bangalore Section, January 1978.

3. Best Cadet, National Cadet Corps, 1976 (Served 1970-1976).

2. Seventh Rank holder, University of Mysore Bachelor of Engineering Examinations, 1976.

1. Government of India National Merit Scholar, 1970-76.

K. Reviews Performed

Reviewed papers for IEEE Transactions on Pattern Analysis and Machine Intelligence
IEEE Transactions on Biomedical Engineering
IEEE Transactions on Medical Imaging
IEEE Transactions on Image Processing
IEEE Transactions on Information Technology in Biomedicine
Journal of Biomechanical Engineering
Medical and Biological Engineering and Computing
Medical Physics
Applied Optics
Optical Engineering
Journal of Electronic Imaging
Computer Vision, Graphics, and Image Processing (CVGIP)

Geophysics
IASTED Journal Control and Computers

Reviewed reports, applications, and projects for Revenue Canada, MRC, NSERC, U.S. National Science Foundation, Israel Science Foundation, Hong Kong University Grants Commission, IEEE, and many universities.

L. Institutions Visited to Provide Lectures and Courses (Outside N. America)

Universidade de São Paulo, São Paulo, SP, Brasil

Universidade Federal de São Carlos, São Carlos, SP, Brasil

Universidade de São Paulo, São Carlos, SP, Brasil

Universidade de São Paulo, Ribeirão Preto, SP, Brasil

Universidade Estadual de Ciencias da Saúde de Alagoas, Maceió, AL, Brasil

Universidade Estadual de Campinas, Campinas, SP, Brasil

Universidade Federal de Uberlândia, Uberlândia, MG, Brasil

Radioclínica, Uberlândia, MG, Brasil

Instituto do Coração, São Paulo, SP, Brasil

Instituto da Criança, São Paulo, SP, Brasil

Universidade Estadual Paulista, Sorocaba, SP, Brasil

Faculdade de Engenharia de Sorocaba, Sorocaba, SP, Brasil

Universidade Federal do Pernambuco, Recife, PE, Brasil

Universidade Federal do Rio Grande do Sul, RS, Brasil

Faculdade SENAC de Ciências Exatas e Tecnologia, (SENAC College of Computational Sciences and Technology), São Paulo, SP, Brasil

Universidad de Sevilla, Sevilla, Spain

École Nationale Supérieure des Télécommunications de Bretagne, Brest, France

Université de Paris VI, Paris, France

Institut Polytechnique de Lyon, Lyon, France

Université de Savoie, Annecy, France

Université de Rennes, Rennes, France

University of Genova, Genova, Italy

Universitatea Politehnica Bucureşti, Bucharest, Romania

State Optical Institute, St. Petersburg, Russia

AZ Corporation and Tomography Association, Moscow, Russia

Tampere University of Technology, Tampere, Finland

University of Manchester, Manchester, UK

Imperial Cancer Research Fund, London, UK

University of Liverpool, Liverpool, UK

Royal Marsden Hospital, London, UK

University of Twente, Enschede, The Netherlands

Alexandria University, Alexandria, Egypt

University Hospital, Kuala Lumpur, Malaysia

Universiti Sains Malaysia (KCP), Tronoh, Malaysia

Universiti Sains Malaysia, Penang, Malaysia

National University of Singapore, Singapore

King Mongkut's Institute of Technology, Bangkok, Thailand

University of Hong Kong, Hong Kong

Shanghai Jiao Tong University, Shanghai, China

The Ninth People's Hospital, Shanghai, China

Northern Jiao Tong University, Beijing, China

Tsinghua University, Beijing, China

Beijing University of Posts and Telecommunications, Beijing, China

Tokyo Institute of Technology, Tokyo, Japan

Nagoya Institute of Technology, Nagoya, Japan

Niigata University, Niigata, Japan

Indian Institute of Science, Bangalore, India

Tata Institute of Fundamental Research, Bombay, India

Indian Institute of Technology, Bombay, India

Indian Institute of Technology, New Delhi, India

Indian Statistical Institute of Technology, Kolkatta, India

College of Engineering, Pune, India

S.J. College of Engineering, Mysore, India

Center for Biomedical Engineering, Indian Institute of Technology, New Delhi, India

P.E.S. College of Engineering, Mandya, India

G.E. India Technology Centre,
Bangalore, India

M.S. Ramaiah School of Advanced
Studies, Bangalore, India

Manipal Institute of Technology,
Manipal, India

Fischer Imaging, Denver, CO

M. Research Grants Held (selected items)

NSERC Research Grant, "Digital Image Processing Techniques for the Detection and Quantitative Analysis of Diagnostic Features in Retinal Images", $ 42,020 p.a., 2007-2012.

Canadian Breast Cancer Foundation – Prairies/NWT Chapter, "Detection of Architectural Distortion in Prior Mammograms of Interval Cancer Cases", $22, 000 p.a., 2006 – 2008 (R.M. Rangayyan, J.E.L. Desautels).

Kids Cancer Care Foundation of Alberta, Summer Studentships, "Computer-aided segmentation and analysis of the tumor in neuroblastoma", $6, 000, p.a., 2003 – 2005.

NSERC Research Grant, "Analysis of architectural distortion in mammograms", $ 44,470 p.a., 2002-2007.

Kids Cancer Care Foundation of Alberta, "Computer-aided analysis of neuroblastoma", $11, 023, 2001-2002.

The Alberta Heritage Foundation for Medical Research, $ 125,000, "High-resolution medical image display devices and computer workstations", 2001 (R.M. Rangayyan, J.E.L. Desautels).

{Items prior to 2001 not listed.}

N. Technology Transfer, Patents, and Consulting Activities

9. Consultant to Fischer Imaging, Denver, CO. 2004 – 2005.

8. U.S. Patent 6,537, 233 B1 on "Auditory display of knee joint vibration signals" (March 5, 2003). US patent application serial no. 09/706,987; filed November 6, 2000. Canadian patent application no. 2,235,236. R.M. Rangayyan, S. Krishnan, G.D. Bell, and C.B. Frank. Assignee: University Technologies International Inc. (UTI #435.1).

7. AHFMR Technology Commercialization Grant, "Development of a non-invasive device for diagnosing knee-joint injury", $ 34,925, 2000-2001. (With Mind to Market Solutions Inc., Calgary.)

6. Consultant to VitalSines, 2000.

5. Consultant to Hycal Energy Research Laboratories Ltd.

4. Software for computer-aided analysis of mammograms, licensed to researchers at the University of Paris, Paris, France; Cleveland Clinic Foundation, Cleveland, OH; and the University of Regina, Regina, Saskatchewan; through University Technologies International Inc., 1999-2000.

3. Government of Alberta, Department of Technology, Research and Telecommunications; Grant received for the 1st stage of the project on "High resolution Digital Teleradiology" (Economic Analysis), with I.T.T. Export Corporation, Calgary (Dr. N.A. Goswami), $20,000, 1988.

2. Consultant to V.T.A. Photogrammetrics Consultants Ltd., Calgary, 1987-89.

1. Consultant to I.T.T. Export Corporation and Tectran Research Inc., Calgary, 1987-90.

O. Teaching and Curriculum Development

At the Tampere University of Technology, Tampere, Finland: Biomedical Signal Analysis, 2000, 2007.

At the University of São Paulo, São Paulo, SP, Brazil: PEE830 Digital Image Processing, 1994.

At the University of Calgary:

ENGG 213- Engineering Computation;
ENGG 215- Engineering Practice, Design, and Communication;
ENGG 233- Computing for Engineers I;
ENGG 333- Computing for Engineers II;
ENGG 303- Electrical Circuits and Machines;
ENGG 323- Systems and Instrumentation;
ENEL 327- Signals and Systems;
ENEL 563- Biomedical Signal Analysis;
ENEL 599- Electrical Engineering Project;
ENEL 593- Digital Filters;
ENEL 697- Digital Image Processing.

"Indian Classical Music: Lecture-demonstration on the flute, sitar, and tabla", Guest Lectures for GNST 359 Introduction to World Music, SAST 315 Understanding South Asia; and MUED 671.06 Culture Studies and World Music (with U. Mazumdar).

At the Indian Institute of Science, Bangalore, India: ES9-202- Digital Signal Processing.

At the University of Manitoba:

24.208- Electric Circuits;

24.358- Signal Analysis IIIE;
24.426- Communication Systems;
24.815- Digital Signal Processing;
24.822- Digital Image Processing;

Developed a new Fourth-year B.Sc. Electrical and Computer Engineering elective course ENEL 563 Biomedical Signal and Image Analysis, including a textbook, lecture notes, lab exercises, and problem-solution sets, 1997.

Developed the curriculum for a graduate program on Computer Vision for Universiti Sains Malaysia, Ipoh, 1994.

Developed the curriculum for a new course ENGG333 Advanced Engineering Computation, as member of a subcommittee, 1990.

Developed a graduate program curriculum in Biomedical Engineering at The University of Calgary, as Chairman of a sub-committee, 1985-89.

Developed a new set of computer program examples and lab assignments for ENGG 327/213 Engineering Computation, 1985.

Developed a new graduate course ENEL 697 "Digital Image Processing" at Electrical Engineering Department, University of Calgary, 1985. Laboratory facilities were also developed to support the course.

Developed procedures on the HP9816 computer for lab experiments on Fourier analysis, AM, and FM, for course 24.358, 1984 (with R. Lehner).

Formulated new graduate courses 24.830 "Computer Vision", 24.829 "Imaging in Biomedical Engineering" (with R. Gordon), and "Image Processing for Remote Sensing" (with Working Group for "Imaging and Remote Sensing"), at University of Manitoba, Department of Electrical Engineering, 1984.

Developed a new lab experiment on "Threshold effects in FM systems" for course 24.426 Communication Systems, 1983 (with R. Lehner).

Developed a new graduate course 24.822 "Digital Image Processing" at the University of Manitoba, Department of Electrical Engineering, 1983.

P. Student and Staff Supervision

P1. Graduate students being supervised at present:

1. Sansira Seminowich (M.Sc.), 2004 – .., "Image processing techniques for the analysis of renal tissue samples".

2. Ilya Kamenetsky (M.Sc.), 2004 – .., "Image processing techniques for the analysis of renal tissue samples".

3. Thanh Minh Nguyen (M.Sc.), 2004 – .., "Fractal analysis of breast masses in mammograms".

4. Douglas Frey (M.Sc., Cosupervisor), 2005 – .., "Analysis, modeling, and reproduction of an acoustic environment using computer simulation".

5. Shantanu Banik (M.Sc.) 2006 – .., "Segmentation and analysis of computed tomographic images of neuroblastoma".

6. Yunfeng Wu (Ph.D., Beijing University of Posts and Telecommunications, Cosupervisor), 2006 – .., "Biomedical signal analysis".

7. Xiaolu (Iris) Zhu (M.Sc.), 2007 – .., "Biomedical image analysis".

P2. Graduate Theses Completed:

30. Shormistha Prajna (M.Sc.), 2006 – 2007, "Detection of architectural distortion in prior mammograms using Gabor filters, phase portraits, fractal dimension, and texture analysis".

29. Fábio José Ayres (Ph.D.), 2002 – 2007, "Computer-aided Diagnosis of Architectural Distortion in Mammograms".

28. Randy Hoang Vu (M.Sc.), 2004 – 2006, "Strategies for three-dimensional segmentation of the primary tumor mass in computed tomographic images of neuroblastoma".

27. Yuhong (Kay) Liu (M.Sc., Cosupervisor), 2003 – 2005, "Application of Efron's bootstrap methods to evaluate the performance of neural networks in the classification of mammographic features".

26. Xiaozheng (Eileen) Wang (M.Sc., Cosupervisor), 2003 – 2004, "Application of data mining to mammographic data".

25. Hanford John Deglint (M.Sc.), 2003 – 2004, "Image processing algorithms for three-dimensional segmentation of the tumor mass in computed tomographic images of neuroblastoma".

24. Margaret Hilary Alto (Ph.D.), 1999-2003, "Indexed atlas of mammograms for computer-aided diagnosis of breast cancer".

23. Ricardo José Ferrari (Ph.D., Co-supervisor, University of São Paulo, São Carlos, SP, Brazil), 1999-2002, "Computational detection of asymmetry between mammograms" (in Portuguese).

22. Naga Ravindra Mudigonda (Ph.D.), 1997-2001, "Image analysis methods the detection and classification of mammographic masses".

21. Sridhar Krishnan (Ph.D.), 1996-99, "Adaptive signal processing techniques for analysis of knee joint vibroarthrographic signals".

20. Liang Shen (Ph.D.), 1992-98, "Region-based adaptive image processing techniques for mammography".

19. Roseli de Deus Lopes (Ph.D.- University of Sao Paulo, Brazil), 1995-98, "Region-based techniques for processing three-dimensional images with applications in volume visualization".

18. Antonio Cesar Germano Martins (Ph.D.- University of Sao Paulo, Brazil), 1995-97, "Auditory display and sonification of images with texture".

17. Nema El-Faramawy (Ph.D.- Alexandria University, Egypt), 1994-96, "Measures of acutance and shape for classification of breast tumors".

16. Arup Das (M.Sc.), 1995-96, "Region-based image processing".

15. Sridhar Krishnan (M.Sc.), 1994-96, "Adaptive filtering, modeling, and classification of knee joint vibroarthrographic signals".

14. William Rolston (M.Sc.), 1992-94, "Directional Image Analysis".

13. Yiping Shen (M.Sc.), 1992-94, "Transmission Characteristics and Localization of Vibroarthrographic Signals".

12. Zahra Kazem-Moussavi (M.Sc.), 1992-93, "Analysis of Knee Sound Signals via Least Squares Modeling".

11. Joseph Provine (M.Sc.), 1991-92, "Peanoscanning for Image Compression".

10. Hieu N. Nguyen (M.Eng. Part-time), 1986-92, "Object-based Contrast Enhancement".

9. Djamel Boulfelfel (Ph.D.), 1989-92, "Restoration of Nuclear Medicine Images".

8. Tamer F. Rabie (M.Sc.), 1991-92, "Adaptive-Neighborhood and Iterative methods for Image Restoration".

7. Liang Shen (M.Sc.), 1991-1992, "Shape analysis of mammographic calcifications".

6. Gopinath R. Kuduvalli (Ph.D.), 1989-92, "Image data compression for high-resolution digital teleradiology".

5. Sanjeev Tavathia (M.Sc.), 1989-1991, "Analysis of Knee Joint Vibration Signals by Linear Prediction".

4. William M. Morrow (M.Sc.), 1989-1990, "Region-based Image Processing Techniques with Application to Mammography".

3. Timothy C. Hon (M.Sc), 1986-1988, "Restoration of Gamma Camera-Based Nuclear Medicine Images".

2. Subhasis Chaudhuri (M.Sc.), 1985-1987, "Digital Image Processing Techniques for Quantitative Analysis of Collagen Fibril Alignment in Ligaments".

1. Richard J. Lehner (M.Sc.), 1983-1985, "A three-channel microcomputer system for quantitative analysis of the phonocardiogram, electrocardiogram and carotid pulse signals".

P3. Undergraduate Theses/ Projects:

18. Chad Erven, "Implementation of a statistical analysis method for vibroarthrographic signals on an embedded TigerSHARC processor", 2007.

17. Foad Oloumi, Faraz Oloumi, and Peyman Eshghzadeh-Zanjani, "Detection and Analysis of Blood Vessels in the Retina", 2006 – 2007.

16. Thanh Minh Nguyen, "Fractal analysis of mammographic masses", 2004.

15. Heather Bosnak, Ramanpreet Grewal, James Howland, and Ben Liu, "An indexed atlas of digital mammograms for computer-aided diagnosis of breast cancer", 2004-2005.

14. Howard Lau, Kelvin Mok, Donald So, and Courtney Tse, "An indexed atlas of digital mammograms for computer-aided diagnosis of breast cancer", 2003-2004.

13. Leslie Anderson, Jackalynn Sproat, Diane Janzen, Wai Ki Chau, "Computer workstation for analysis and classification of knee joint vibroarthrographic signals for non-invasive diagnosis of articular cartilage pathology", 1998-99 (with G.D. Bell).

12. Philip Arsenault, Sharon Ellingsen, Shanif Lakhani, Paul Thomson, Mike Mulligan, Minesh Kuttlerywala, John Liu, "Computer workstation for analysis and classification of knee joint vibroarthrographic signals for non-invasive diagnosis of articular cartilage pathology", 1997-98 (with G.D. Bell).

11. Ram Reddy, "A study of the optimal threshold for the recursive least squares method of segmentation", 1994 Winter.

10. Salahuddin Elkadiki, "Objective characterization of image acutance", 1993 Winter.

9. Kenny Tse, "Quantitative wellbore fracture analysis from electrical images", 1992 Fall.

8. Terry Baydock, "Image coding and compression for digital teleradiology", 1983-84 (with R. Gordon and J. Dunning).

7. Patricia Palanuk, "Homomorphic deconvolution of EMG signals", 1983-84.

6. A. Wong, "Microcomputer system for arrhythmia monitoring", 1983-84.

5. H.K. Wong, "Microcomputer system for adaptive neighborhood image processing", 1983-84 (with R. Gordon and J. Dunning).

4. Brent Kizuik, "Automated control of a rotating microscope system", 1982-83 (with R. Gordon).

3. Kirby Jaman, "Optimal display of limited-view computed tomograms in 3D", 1982-83 (with R. Gordon).

2. Richard Lehner, "Microprocessor-based heart sound analyzer", 1982-83.

1. Curtis Quinn, "Video simulation of steerable x-ray microbeam imaging", 1982-83 (with R. Gordon).

P4. Supervision of Other Research Staff:

39. Denise Guliato, Post-doctoral Fellow from the Federal University of Uberlândia, Brazil, 2006 – 2007, "Computer-aided diagnosis of breast cancer".

38. Begoña Acha Piñero, Visiting Researcher from the University of Seville, Spain, July – August 2004, "Detection of calcifications in mammograms".

37. María del Carmen Serrano Gotarredona, Visiting Researcher from the University of Seville, Spain, July – August 2004, "Detection of calcifications in mammograms".

36. Randy Hoang Vu, "Medical image analysis", NSERC USRA, May – August, 2004.

35. Túlio César Soares dos Santos André, from Universidade de São Paulo, Ribeirão Preto, SP, Brazil, "Neural networks for the detection of breast cancer", January – April 2003.

34. Antonio Cesar Germano Martins, from the Faculty of Engineering, Sorocaba, São Paulo, SP, Brazil, July 2001, "Analysis of texture in images".

33. Fábio José Ayres, from the University of São Paulo and Faculdade SENAC de Ciências Exatas e Tecnologia, (SENAC College of Computational Sciences and Technology), São Paulo, SP, Brasil, "Segmentation and estimation of the histological composition of the tumor mass in computed tomographic images of neuroblastoma", March - April 2001, January - February 2002.

32. Sílvia Delgado Olabarriaga, from the Federal University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil, November 2000, "Subjective and objective analysis of image sharpness".

31. Jérôme Jouffroy, Internship Student from Université de Savoie, Annecy, France, 1999, "Analysis of asymmetry in mammographic images".

30. Hilary Alto, 1998, Part-time Research Associate, "Computer-aided Diagnosis of Breast Cancer" (with J.E.L. Desautels).

29. Begoña Acha Piñero, Visiting Researcher from the University of Seville, Spain, 1998, "Medical Image Processing".

28. María del Carmen Serrano Gotarredona, Visiting Researcher from the University of Seville, Spain, 1998, "Medical Image Processing".

27. Denise Guliato, Visiting Researcher from the Federal University of Uberlandia, Brazil, 1998, "Segmentation of breast tumor regions in mammographic images".

26. Mihai Ciuc, Visiting Research Associate from University of Bucharest, Romania, 1997, "Adaptive neighborhood filtering of color images".

25. Marcelo Knörich Zuffo, Visiting Research Associate from Universidade de São Paulo, São Paulo, SP, Brasil, 1997, "Iconographic display of mammographic features for computer-aided diagnosis of breast cancer".

24. Olivier Menut, Internship Student from Institut National Polytechnique de Grenoble, France, 1997, "Detection, shape analysis, and classification of breast tumors in mammographic images", (with J.E.L. Desautels).

23. Yiping Shen, Research Assistant, 1994-95, "Clinical evaluation of computer-aided enhancement and analysis of mammograms for the diagnosis of early breast cancer", (with J.E.L. Desautels).

22. Umi Kalthum Ngah, Visiting Research Associate, Universiti Sains Malaysia, Tronoh, Malaysia, "Digital Image Processing with applications to Mammography", 1993.

21. Salahuddin Elkadiki, "Image Acutance", 1993.

20. Yiping Shen, Research Assistant, "Analysis of ligament vascularity", 1991 (with Dr. R.C. Bray).

19. William Rolston, Research Assistant, "Directional Image Processing", 1991.

18. Sanjeev Tavathia, Research Assistant, "Heart sound signal analysis", 1991.

17. Kevin Eng, Summer Research Assistant, "Digital image processing techniques for the analysis of vascularization of ligaments in response to injury", 1990 (with Dr. R.C. Bray).

16. Dr. Raman Paranjape, Post-doctoral Research Associate, "Digital Image Processing Techniques for the Analysis of Mammograms", 1990-92 (with Dr. J.E.L. Desautels).

15. Theo Smit, Research Associate, "Digital Signal Processing Techniques for Non-invasive Detection and Classification of Cartilage Pathology in the Knee", 1989 (with Dr. C. Frank and Dr. G.D. Bell).

14. Dr. Yuanting Zhang, Post-doctoral Research Associate, "Digital Signal Processing Techniques for Non-invasive Detection and Classification of Cartilage Pathology in the Knee", 1989-94 (with Dr. C. Frank and Dr. G.D. Bell).

13. Dr. Zhi-Qiang Liu, Post-Doctoral fellow (CDC PACER Fellow and AHFMR Fellow), "Quantitative analysis of collagen alignment in ligaments for optimization of healing", 1987-90 (with Dr. C. Frank)

12. Richard Smith, "Knee joint sound signal analysis", May-August, 1987 (with C. Frank and D. Bell).

11. Richard Smith, "Biomedical Signal Analysis - Electrodiagnosis and Acoustodiagnosis", May-August, 1986, (with C. Frank and D. Bell).

10. D. Mitchell, 1986, "Reconstruction and restoration of seismic tomography in bore holes".

9. Hieu Nguyen, "Adaptive Neighbourhood Image Processing Applied to Mammograms", December 1985, April - August 1986.

8. Hieu Nguyen, Duane Webb, "Digital Processing of Electron Micrographs of Rabbit Ligament Collagen Fibers", May-August, 1985 (with C. Frank).

7. Mike Bauer, Ed Block, "Phonocardiogram Signal Processing", May-August, 1985.

6. Doug Den Hoed, Bill Royan, "Digital Image Processing using Adaptive Neighbourhoods", Feb.-May 1985.

5. Tim Strecker, Part-time Research Engineer, "Digital Image Processing", 1984-85.

4. R.J. Lehner (with R. Gordon), 1984 "Digital subtraction angiography using adaptive neighborhood image processing".

3. M.L. Miller, 1984, "Identifying and locating heart sound sources in 3D: A preliminary study".

2. Greg Kozier, Part-time Research Associate, "Evaluation of the SPARTAF algorithm on the EMI CT scanner", 1983 (with R. Gordon).

1. Paul Soble, Part-time Research Associate, "Homomorphic deconvolution of geometric artifacts in limited-view computed tomography", 1982-84 (with R. Gordon).

Q. External Administrative and Organizational Service (Selected Items)

Journal Advisory Board, International Journal of BioSciences and Technology, 2008 –.

Co-Chair and Co-Editor of proceedigs, IASTED International Conference on Telehealth, Banff, Alberta, Canada. 19 – 21 July 2005.

External Examiner, Chinese University of Hong Kong, Electronics Engineering, 2003 – 2006.

Associate Editor: IEEE Transactions on Biomedical Engineering, 1989-96.

Program Co-Chair, 20th Annual International Conference of the IEEE EMBS, Hong Kong, October 1998.

Track Chair for Imaging, 18th Annual International Conference of the IEEE EMBS, Amsterdam, The Netherlands, October 1996.

Organized and Chaired a session on "Biomedical Engineering Education: An International Perspective", ASEE Conference, Edmonton, 26-29 July 1994. (with Z. Koles).

Member, IEEE EMBS Conference Committee, 1992-99.

Member, Scientific Program Committee and Editorial Board, International Symposium on Computerized Tomography, Novosibirsk, Russia, 10-14 August, 1993.

Program Chair and Co-Editor, 15th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 28-31, 1993, San Diego, CA.

Chairman (founding), IEEE EMBS Southern Alberta (Calgary) Chapter, 1991-93.

Canadian Regional Representative to the Administrative Committee (AdCom) of the Engineering in Medicine and Biology Society of the IEEE, 1990-93.

Member, Canadian Standards Association- Committee on Programming Languages-Fortran Working Group (on the development of the new standard Fortran90), 1989-94.

Program Chairman, Organizing Committee for the IEEE Western Canada Exhibition and Conference on "Telecommunication for Health Care: Telemetry, Teleradiology, and Telemedicine", July 6-7, 1990, University of Calgary, 1988-90.

Chairman, Local Arrangements Committee, Optical Society of America Topical Meeting on "Industrial Applications of Computed Tomography", Hecla Island, Manitoba, August 1984.

R. University Administrative and Organizational Service (Selected Items)

Associate Vice-President (Research), 2000-2002.

Associate Head (Undergraduate Studies), Department of Electrical and Computer Engineering, University of Calgary, 1993-94.

Acting Head, Department of Electrical and Computer Engineering, University of Calgary, 1991-92.

Chair, Faculty of Engineering Infomatics Committee, 1996-97.

Chair, Faculty Advisory Committee on Computing, 1986-87, Member 87-88.

Chair, Committee for Graduate Studies Curriculum in Biomedical Engineering, Faculty of Engineering, University of Calgary, 1985-90.

IEEE Student Branch Counselor, University of Calgary, 1985-90.

S. Community Service (Selected Items)

President, Raga Mala Music Society of Calgary, 1991-93, Treasurer 1989-91.

Judge, 1988 Science Fair, St. Stephen's School and Father Whelihan School.

President, Southern India Cultural Association, Calgary, 1985, (1986).

Volunteer Tutor, Kendriya Vidyalaya (Central School), Indian Institute of Science, Bangalore, 1979-80.

T. Visiting Appointments Held

University of Liverpool, Liverpool, UK, 2007 – 2010.

Beijing University of Posts and Telecommunications, Beijing, China, 2006 – 2009.

Manipal Institute of Technology, Manipal, Karnataka, India, 2006 – 2009.

Tampere University of Technology, Tampere, Finland, April 1999, April 2000, August 2007.

Lerner Research Institute, Cleveland Clinic Foundation, Cleveland, OH, December 1999.

Universitatea Politehnica din Bucureşti, Bucharest, Romania, April 1996.

Escola Politécnica, Universidade de São Paulo, São Paulo, SP, Brasil, 1994-present.

Department of Electrical Engineering, Indian Institute of Science, Bangalore, India, August 1994, July-December 1988.

Département Image et Traitement de l'Information, Télécom Bretagne- École Nationale Supérieure des Télécommunications de Bretagne, Brest, France, May-June 1995, July 1999.

U. International Research Collaboration and Developmental Activities

I have given many lectures, research seminars, and tutorials on digital image processing, computer vision, medical imaging and image analysis, biomedical signal analysis, and related topics, as well as collaborated with researchers at universities, institutes, and research organizations in India, Canada, U.S.A., Brazil, Argentina, Uruguay, Chile, U.K., Russia, The Netherlands, Egypt, France, Spain, Italy, Romania, Malaysia, Thailand, Japan, Hong Kong, and China.

Computer programs we have developed for medical image analysis and other applications have been used or are being used by research groups in the U.S., China, Brazil, Argentina, France, Spain, Romania, and Malaysia.

V. News Media Coverage – Articles and Interviews

"University professor the first in Canada to receive acknowledgement from major international society", by Laurie Wang, Newsletter of the Faculty of Medicine, University of Calgary, July 24, 2007.

"Um software amigo do peito", interview article by Arlete Mattos, with Dr. Paulo Mazzoncini de Azevedo Marques, published in USP-Ribeirão, newspaper of the University of São Paulo, Ribeirão Preto, 13 March 2006. The same matter was also published on the website of the Clinical Hospital of the University of São Paulo, Ribeirão Preto.

"Programa de compuatdor no combate ao câncer de mama", interview article by Angelo Davanço, with Dr. Paulo Mazzoncini de Azevedo Marques, published in Jornal a Cidade Ribeirão Preto, SP, Brazil, 9 March 2006.

TV Clube (Bandeirantes) interview by Roberto Ribeiro, 10 Feb. 2006, on computer-aided diagnosis of breast cancer, with Dr. Paulo Mazzoncini de Azevedo Marques, Ribeirão Preto, SP, Brazil.

RP9 TV interview by Angela Pepe, 9 Feb. 2006, on computer-aided diagnosis of breast cancer, with Dr. Paulo Mazzoncini de Azevedo Marques, Ribeirão Preto, SP, Brazil.

"A Second Opinion", interview article by Malwina Gudowska, Avenue magazine, November 2005, pp 26 – 28.

"Group Creates an Information Autobahn", part of Feature Article by Nordahl Flakstad, in The PEGG: Newsletter of the Association of Professional Engineers, Geologists, and

Geophysicists of Alberta, 32(2):18, February 2004.

"U of C Salutes its Stars", On Campus, University of Calgary, 14 November 2003.

"SPIE's in the Faculty?", Enginuity, Faculty of Engineering, University of Calgary, Fall 2003.

"Engineering prof named SPIE Fellow", On Campus, University of Calgary, 3 October 2003.

"Listen, Honey...". Interview on CBC Radio on my CD and the classical music of India. April 2003. (With Utpal Mazumdar.)

"Listen, Honey...". Live interview and performance on CJSW Radio on my CD and the classical music of India. April 2003. (With Utpal Mazumdar.)

"If you have the time...". Interview with CBC Radio on my CD and the classical music of India. November 2000. (With Utpal Mazumdar.)

"Engineering better breast cancer screening", CBC Radio interview with Jeff Collins, June 2000.

"The Music of North India". Cranbrook Daily Townsman. 22 September 1999. Cover-page photo and caption on concert sponsored by the College of the Rockies, Cranbrook, BC.

"Engineer Enhances Cancer Screening", Robert Walker, Interview article, Calgary Herald, 24 April 1999.

"Better Breast Cancer Screening", Interview article, Alberta Heritage Foundation for Medical Research (AHFMR) Newsleter, March/April 1999, p7.

"Computer-aided diagnosis of breast cancer". Major media event was organized on 23 April 1999 by the Alberta Foundation for Medical Research (AHFMR): about 10 news, radio, and TV reporters visited our laboratory. According to Rhonda Lothammer of the AHFMR, the interview was broadcast or published by the A Channel, Calgary Herald, Calgary Sun, CFCN, CICT, QR77, Shaw TV, CBC News, CHQR, CHQT, and CISN (Edmonton).

"Computer-aided diagnosis of breast cancer". Live interview via telephone for QR77 Radio, 23 April 1999.

"Engineering computers to diagnose breast cancer earlier". Featured in "Selected Alberta Science and Research Success Stories: Volume III", published by ASRA: Alberta Science and Research Authority, September1999, p29.

"Increasing precision in mammograms", Progressions... AHFMR Funded Cancer Research. Alberta Heritage Foundation for Medical Research Triennial Report. 1999, p22.

"Seeing Mammomograms More Clearly". Arch, 1999 Summer, p7.

"In Tune With You". Interview with CBC Radio on the classical music of India and my CD, 25 November 1998. (With Utpal Mazumdar.)

"Computer-aided diagnosis of breast cancer", Presentation at the opening ceremony and media event of the Multimedia Advanced Computational Infrastructure (MACI) facility at the Rozsa Centre, University of Calgary, 28 September 1998.

"Computer-aided diagnosis of breast cancer", Interview with the television station "A Channel", 28 September 1998.

"Classical music of India", Interview and live performance on the flute, CJSW Radio, 15 March 1998. (With Utpal Mazumdar.)

"Just In Time ...just for you!" Interview with CBC Radio on the classical music of India and my CD, 10 February 1998. (With Utpal Mazumdar.)

Classical music of India and the bamboo flute, TV news-hour interview with Renata Canales (in Portuguese), EPTV Ribeirão Preto, São Paulo, Brazil, July 1998.

"Computer-aided diagnosis of breast cancer", Interview with CBC Radio (live broadcast), 24 March 1998.

"Engineering Tools for Breast Cancer Screening", Enginuity: Newsletter of the Faculty of Engineering and the Engineering Associates Program, University of Calgary, Spring 1998, p1,3.

"Prof engineers better tools for breast cancer screening", University of Calgary Gazette, Interview article, 23 March 1998, p1,2.

"Os incríveis sons que vêm da Índia" (The incredible sounds that come from India – in Portuguese), Gustavo Guimarães, Interview article, Jornal da Universidade de São Paulo, São Paulo, Brazil, 3-9 April 1995, p12.

"Computers Lend Healing Hand", Sharon Pearce, Interview article, The PEGG: Newsletter of the Association of Professional Engineers, Geologists, and Geophysicists of Alberta, October 1993.

"A twist of fate: Researchers at University of Calgary train electron microscopes and a supercomputer on the problem of ligament injuries", J. Thornton (interviewing R.M. Rangayyan and C.B. Frank), Logic: Control Data Corporation, 1987 Autumn Issue, pp. 8-13.

APPENDIX B

1. U.S. Patent No. 4,829,381 (the '381 Patent)

2. File History of the '381 Patent

3. U.S. Patent No. 4,489,349

4. Digital Image Processing", by Gonzalez R.C. and Wintz P., (Addison-Wesley, Reading, MA, 1977)

5. Digital Image Processing", Second Edition, by Gonzalez R.C. and Wintz P., (Addison-Wesley, Reading, MA, 1987)

6. "Computer Image Processing and Recognition", by Hall E.L., (Academic, New York, NY, 1979)

7. "Digital Picture Processing", by Rosenfeld A. and Kak A., (Academic, San Diego, CA, Vol. 1-2, 1982)

8. "Digital Image Enhancement and Noise Filtering by Use of Local Statistics," by Jong-Sen Lee, (IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-2, No. 2, pp. 162-168, March 1980)

9. "Refined filtering of image noise using local statistics", by Jong-Sen Lee, Computer Graphics and Image Processing, 1981, 15: 380-389.

10. "Real-Time Adaptive Contrast Enhancement", by Patrenahalli M. Narendra and Robert C, Fitch (IEEE Transaction on Pattern Analysis and Machine Intelligence, VOL. PAMI-3, No. 6, November 1981)

11. "Digital Image Enhancement: A Survey", by David C. Wang, Anthony H. Vagnucci and C.C. Li, (Computer Vision, Graphics, and Image Processing, Vol. 24, pp 363-381 (1983))

12. "Feature Enhancement of Film Mammograms using Fixed and Adaptive Neighborhoods", by Gordon R and Rangayyan RM, Applied Optics, 1984, 23(4): 560-564

13. U.S. Patent No. 4,528,584

14. U.S. Patent No. 4,654,710

15. U.S. Patent No. 4,789,933

16. Progressive Refinement of Raster Images," by Kenneth R. Sloan, Jr. and Steven L. Tanimoto, (IEEE Transactions on Computers, Vol. C-28, No. 11, November 1979)

17. Joint Claim Construction Statement (Corrected)

APPENDIX C

Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Gonzalez (1987)

Claim Limitation	Polaroid Construction	Gonzalez (1987)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Gonzalez teaches systems which enhance image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel *(x,y)*. Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed	**Function:** Gonzalez teaches using averages for image enhancement. (Gonzalez, p. 161). In Equation 4.3-1, a formula is provided to calculate the arithmetic mean (average) of a number of pixel values from a selected neighborhood around the pixel being processed, indicated by *S*. Gonzalez teaches that a 3 × 3 neighborhood including nine pixels could be used, but also that "we are not limited to square neighborhoods". The intermediate calculated value of an average taught by Gonzalez may be implemented in a computing device, such as a software program running on a computer.

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	to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value." **Structure**–a low pass filter or block average and equivalents thereof.	**Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). I agree with the above-statement. As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies	**Function:** Gonzalez teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Gonzalez, p.159, last paragraph to p. 160, first and second paragraph). The value of the pixel being processed, referred to in Gonzalez as *f(x,y)*, is transformed into a new pixel value, referred to as *g(x,y)* using the transfer function illustrated by Equation (4-2-14). (Gonzalez, p. 160). This transfer function uses the value of the pixel *f(x,y)* in its computations. This transfer function also uses the calculated intermediate value - the mean of the pixel values for a group of pixels including the pixel being processed, referred to as *m(x,y)* in its computation. The result of this computation using the value of the pixel *f(x,y)* and the average value *m(x,y)* results in a transformed value for the pixel *g(x,y)*. Gonzalez teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the values for a group of pixels that includes the subject pixel) over a value that lies within a range bounded by definite limits. The value of the pixel being processed, referred to as *f(x,y)*, is transformed into a new pixel value, referred to as *g(x,y)* using the following transfer function illustrated by Equation (4-2-14): $g(x,y)=A(x,y)\times[f(x,y)-m(x,y)]+m(x,y)$. (Gonzalez, p. 160). The transformation function *g(x,y)*, therefore, transforms an original pixel value into a new pixel value using a gain referred to as *A(x,y)* that is defined as follows: $A(x,y)=\frac{k\times M}{\sigma(x,y)}$ for $0<k<1$. (Id.). When the gain *A(x,y)* is replaced with its definition in the equation and multiplied out across, the transfer function becomes: $g(x,y)=\frac{k\times M\times f(x,y)}{\sigma(x,y)}-\frac{k\times M\times m(x,y)}{\sigma(x,y)}+m(x,y)$. The equation above shows that *f(x,y)* is transformed into *g(x,y)* using a function selected as a ratio of the mean of pixel values for a group of pixels that includes the subject pixels over the standard deviation, *σ(x,y)* of the pixels in the group. The standard deviation is the average deviation of a pixel value from the average pixel

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of the average electronic information signal.	within the range of possible values", "*dynamic range of the electronic information signals*" should be construed to mean "value that lies within the range of possible values", "*average electronic information signal*" should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value" **Structure** $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Gonzalez, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value and transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value over a value within a range of values. **Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as *SS* is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Gonzalez is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Gonzalez reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Gonzalez reference in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Gonzalez (1987)
2. The system of claim 1 herein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, *A(x,y)*. (Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, *K*, by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq. 4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, *K*, with the mean value of the neighboring pixels so that the gain would increase in areas of low light or high light. Therefore, I believe that claim 2 is obvious in view of Gonzalez.

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Claim Limitation	Polaroid Construction	Gonzalez (1987)
3. The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.	No proposed construction.	Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function g(x,y) applies a local gain factor A(x,y) to the difference between the pixel value being processed f(x,y) and the local mean m(x,y) of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor A(x,y) amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

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Claim Limitation	Polaroid Construction	Gonzalez (1987)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Gonzalez teaches methods for enhancing image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel (x,y). Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Gonzalez teaches computing an average value for a selected group of pixels and providing the average value for each group of pixels referred to in Gonzalez as *m(x,y)*. (Gonzalez, pp. 158-163). A neighborhood averaging technique calculates an average luminance value by averaging the luminance values of a selected group of pixels referred to as a neighborhood. (Gonzalez, p. 161, Section 4.3.1, first paragraph). The neighborhood of pixels may be a square, such as a 3 by 3 matrix surrounding a pixel that includes the pixel itself. (Id.) The average is calculated by adding the luminance values of the pixels in the neighborhood and dividing by the number of pixels in the neighborhood. (Gonzalez, p. 161, Equation (4.3-1)). This calculation produces an intermediate calculated value providing pixel information. Thus, Gonzalez teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Gonzalez teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Gonzalez, p.159, last paragraph to p. 160, first and second paragraph). The value of the pixel being processed, referred to in Gonzalez as *f(x,y)*, is transformed into a new pixel value, referred to as *g(x,y)* using the transfer function illustrated by Equation (4-2-14). (Gonzalez, p. 160). This transfer function uses the value of the pixel *f(x,y)* in its computations. This transfer function also uses the calculated intermediate value - the mean of the pixel values for a group of pixels including the pixel being processed, referred to as *m(x,y)* in its computation. The result of this computation using the value of the pixel *f(x,y)* and the average value *m(x,y)* results in a transformed value for the pixel *g(x,y)*. Therefore, Gonzalez teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Gonzalez teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the values for a group of pixels that includes the subject pixel) over a value that lies within a range bounded by definite limits. The value of the pixel being processed, referred to as *f(x,y)*, is transformed into a new pixel value, referred to as *g(x,y)* using the following transfer function illustrated by Equation (4-2-14): $g(x,y) = A(x,y)\times[f(x,y)-m(x,y)]+m(x,y)$. (Gonzalez, p. 160). The transformation function *g(x,y)*, therefore, transforms an original pixel value into a new pixel value using a gain referred to as *A(x,y)* that is defined as follows: $A(x,y)=\frac{k\times M}{\sigma(x,y)}$ for $0<k<1$. (Id.). When the gain *A(x,y)* is replaced with its definition in the equation, the transfer function becomes: $g(x,y)=\frac{k\times M}{\sigma(x,y)}\times[f(x,y)-m(x,y)]+m(x,y)$ which, in turn, may also be represented as: $g(x,y)=\frac{k\times M\times f(x,y)}{\sigma(x,y)}-\frac{k\times M\times m(x,y)}{\sigma(x,y)}+m(x,y)$ The equation above shows that *f(x,y)* is transformed into *g(x,y)* using a function selected as a ratio of the mean of pixel values for a group of pixels that includes the subject pixels over the

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		standard deviation, $\sigma(x,y)$ of the pixels in the group. The standard deviation is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Gonzalez, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean of the pixel values for a group of pixels that includes the subject pixel) over a value within a range of values (in this case, the standard deviation of the pixels in the group).

Claim Limitation	Polaroid Construction	Gonzalez (1987)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, $A(x,y)$. (Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, K, by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq. 4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, M, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor taught by Gonzalez to further increase the contrast of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of the image using the mean value of the neighboring pixels. In this way, the gain would increase in areas of low light or high light. Therefore, I believe that claim 8 is obvious in view of Gonzalez.

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Claim Limitation	Polaroid Construction	Gonzalez (1987)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	No construction is required. To the extent the court deems a construction necessary, *"determined constant"* should be construed to mean "chosen number."	Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function g(x,y) applies a local gain factor A(x,y) to the difference between the pixel value being processed f(x,y) and the local mean m(x,y) of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor A(x,y) amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

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Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Richard (1987)

Claim Limitation	Polaroid Construction	Richard (1987)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Richard teaches systems for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value."	**Function:** Richard teaches using a block averaging apparatus consisting of filters that receive a plurality of pixel values and output an intermediate value for those pixels. (see Richard, col. 3, lines 16-56). The means for computing a local mean value is made up of a horizontal-filtering device connected in series to a vertical filtering device. (Richard, col. 3, lines 16-20). The local mean value is an intermediate calculated value. These filtering devices provide a value representing the arithmetic mean of a plurality of pixel values in a window (i.e., a block) centered on the pixel being processed. (Richard, col. 3, lines 19-25). This value represents a value that would be obtained by computing the arithmetic mean of pixel values centered around the pixel value being processed. (Richard, col. 4, lines 49-53). Richard, therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

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	Structure–a low pass filter or block average and equivalents thereof.	**Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies	**Function:** Richard teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Richard, Fig. 1). As shown in Figure 1, the value Y_{ij}/M_g is generated from the multiplier component (Richard, Fig. 1, 10) and is dependent on the pixel value Y_{ij}. Richard teaches that the calculated local mean, M_v, is then multiplied by that result. Richard teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values (in this case, the local mean value for a group of pixels M_v) over a value that lies within a range bounded by definite limits. Richard transforms an input signal using the function depicted as element 5 in Figure 1: $Y'_{ij} = Y_{ij} \times \frac{M_v}{M_g} \times k$. (Richard, col. 2, ll. 21-25; Fig. 1). In Figure 1, Richard illustrates the use of the pixel value (referred to as Y_{ij}), a local mean value of a group of pixels, M_v, and a ratio of the local mean value to the global mean value (M_v/M_g) to produce the transformed value of Y_{ij} times the ratio of M_v/M_g and a constant K. (Richard, Figure 1, elements 10-14). The global mean M_v is an intermediate value providing pixel information. (Richard, col. 1, ll. 58-68). The denominator of this ratio, M_g, has a value within a range of possible values. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Richard, therefore, selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which is the local mean value, M_v. Richard also teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean value M_v) over a value within a range of values (in this case, the global mean value, M_g).

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of the average electronic information signal.	within the range of possible values", "*dynamic range of the electronic information signals*" should be construed to mean "value that lies within the range of possible values", "*average electronic information signal*" should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value" **Structure** $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	**Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Richard is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Richard reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Richard in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Richard (1987)
2. The system of claim 1 herein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Richard teaches selecting a transfer function to provide higher contrast to a pixel when a calculated intermediate value represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of the pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6. line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black, i.e., dark, when the local mean value of this pixel is less than the global mean value. (Id.) "In the case of areas which are darker than the general mean value, these areas even have a darker appearance after processing." (Richard, col. 6, lines 10-14). The contrast amplifier also increases the luminance value of the pixel being processed closer to white i.e., light, when the local mean value of the pixel is greater than the global mean value. (Id.) Richard, therefore, teaches selecting the transfer function to provide higher contrast to a pixel when a calculated intermediate value represents a very dark or very light condition.

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Claim Limitation	Polaroid Construction	Richard (1987)
3. The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.	No proposed construction.	Richard teaches a system in which a constant value, *K*, can be adjusted by an operator to control the contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Y_{ij} multiplied by (M_r/M_g), and further multiplied by this constant *K*. (Richard, Fig. 1) An increase in *K* will result in a higher value of Y_{ij}, thereby increasing the contrast. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

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Claim Limitation	Polaroid Construction	Richard (1987)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Richard teaches methods for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Richard teaches "a means for computing a local mean value M_v of luminance of a point being processed." (Richard, Col. 1, ll. 62-63). A horizontal filtering device and a vertical filtering device as shown in Figure 1 of Richard are connected in series to produce the local mean value M_v. (Richard, col. 4, ll. 46-53). The filtering devices receive a sequence of numerical luminance values of points in a field representing an image. Each field of the image consists of multiple lines, for example, 256 lines, and each line has multiple points or luminance values, for example, 512 points. (Richard, col. 3, ll. 32-43). The filtering devices of Richard compute the local mean value for a line from the luminance values of points on the line. (Id.). The local mean value is provided as the mean for the selected group of luminance values. (Richard, see output M_v from element 6 in the single Figure). The local mean value produced by the filtering devices is an expression of the mean value that would be obtained by computing an arithmetic mean. (Id.). Richard, therefore, teaches calculating an intermediate value (in this case, the local mean) for each selected groups of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Richard teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Richard, Fig. 1). As shown in Figure 1, the value Y_{ij}/M_g is generated from the multiplier component (Richard, Fig. 1, 10) and is dependent on the pixel value Y_{ij}. Richard teaches that the calculated local mean, M_v, is then multiplied by that result. Richard teaches, therefore, selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which is the local mean value, M_v.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Richard teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values (in this case, the local mean value for a group of pixels M_v) over a value that lies within a range bounded by definite limits. Richard transforms an input signal using the function depicted as element 5 in Figure 1: $Y'_{ij} = Y_{ij} \times \frac{M_v}{M_g} \times k$. (Richard, col. 2, ll. 21-25; Fig. 1). In Figure 1, Richard illustrates the use of the pixel value (referred to as Y_{ij}), a local mean value of a group of pixels, M_v, and a ratio of the local mean value to the global mean value (M_v/M_g) to produce the transformed value of Y_{ij} times the ratio of M_v/M_g and a constant K. (Richard, Figure 1, elements 10-14). The global mean M_v is an intermediate value providing pixel information. (Richard, col. 1, ll. 58-68). The denominator of this ratio, M_g, has a value within a range of possible values. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Richard, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean value M_v) over a value within a range of values (in this case, the global mean value, M_g).

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Claim Limitation	Polaroid Construction	Richard (1987)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Richard teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors when the local mean, M_v, represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of *Mv/Mg* will be very close to 0 (for very dark pixels) and will be greater than one for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for that pixel and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for that pixel. Richard, therefore, teaches selecting the transfer function to provide higher contrast to a pixel when a calculated intermediate value represents a very dark or very light condition.

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Claim Limitation	Polaroid Construction	Richard (1987)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	No construction is required. To the extent the court deems a construction necessary, *"determined constant"* should be construed to mean "chosen number."	Richard teaches a system in which a constant value, *K*, can be adjusted by an operator "to control the contrast." (Richard, col. 5, lines 55-58). An increase in *K* will result in a higher output pixel value than a lower value of *K* will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

Exhibit 4 (cont.)

APPENDIX E

Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Lee (1980)

Claim Limitation	Polaroid Construction	Lee (1980)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Lee teaches systems for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", "*average*" should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of	**Function:** Lee teaches using a block averager means that receives as input a plurality of pixel values and outputs an intermediate value calculated value for those pixels. (Lee, p. 165, last paragraph to p. 166, first paragraph). Equation 1 on page 166 produces an intermediate calculated value representing the average of these pixels. Lee further teaches that these algorithms are performed on digital computers. (Lee, P. 165, Introduction, line 1-2). As Lee further teaches making his algorithms more computationally efficient, it is evident that the block averager of equation 1 may easily be implemented on a computer. (Lee, P. 165, Introduction, 1st paragraph, last sentence; second paragraph). Therefore, Lee teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

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	calculated intermediate value." **Structure**–a low pass filter or block average and equivalents thereof.	**Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information*	**Function:** Lee teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Lee, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Lee, p. 166, ll. 1-4 after Eq. (4)). Lee teaches transforming an input signal where the transfer function is further selected as a ratio a calculated intermediate value (in this case, the local mean of the pixel values for a group of pixels including the input pixel) over a value that lies within a range bounded by definite limits. The following algorithm of Lee transforms the input pixel by subtracting the local mean from the value of the pixel, multiplying this difference by a gain k and adding the result to the local mean to provide the transformed pixel value $x'_{i,j}$: $x'_{i,j} = m_{i,j} + k(x_{i,j} - m_{i,j})$ where $k = \sqrt{\frac{v_{i,j}}{v_{orig}}}$ (Lee, p. 166, Equation (4)). In the above equation, $x_{i,j}$ represents the value of the input pixel and $m_{i,j}$ the local mean for the pixel at *(i,j)*. The calculation $x_{i,j} - m_{i,j}$ subtracts the local mean from the value of the pixel being processed. The local mean is an intermediate calculated value of a selected group of pixel values including the input pixel. (Lee, p.165, col. 2 last paragraph and p. 166, Equations (1) and (2)). The result of the subtraction operation is multiplied by a gain referred to as *k*. The gain *k* is defined as a ratio of a local standard deviation (i.e., square root of local variance of pixels in a group of pixels) to an original standard deviation (i.e., square root of original variance of pixels in a group of pixels). (Id). When the gain *k* is replaced with its definition in the above equation, the transformation function becomes:

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increases in correspondence with the increase in the value of the average electronic information signal.	*signal"* should be construed as "ratio of that calculated intermediate value over a value that lies within the range of possible values", *"dynamic range of the electronic information signals"* should be construed to mean "value that lies within the range of possible values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value"	$$x'_{i,j} = m_{i,j} + \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot x'_{i,j} - \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot m_{i,j}$$ The standard deviation (i.e., the square root of a variance) is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Lee, therefore, teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed. Lee also teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local means value, $m_{i,j}$) over a value within a range of values (in this case, the original standard deviation).
	Structure $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	**Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Lee is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Lee reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been

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		explained to me, over Lee in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Lee (1980)
2. The system of claim 1 herein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph). "The linear function ... yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee to a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 2 is an obvious extension of Lee.

Claim Limitation	Polaroid Construction	Lee (1980)
3. The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.	No proposed construction.	Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a higher output pixel value than a lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

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Claim Limitation	Polaroid Construction	Lee (1980)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Lee teaches methods for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Lee teaches a method in which a mean value for each input pixel is derived from the local mean of all pixels within a fixed range surrounding the input pixel. (Lee, p. 165, Abstract, ll. 8-10; p. 165, col. 2, Introduction, ll. 17-22). A two-dimensional array stores a luminance value for each pixel of an image. (Lee, p. 165, col. 2, last paragraph). A local mean $m_{i,j}$ is calculated over a window having a predetermined number of rows and columns. (Lee, p. 166, Equation 1). The window is a rectangular region surrounding the input pixel. Equation 1 sums all the luminance values in the surrounding region and divides by the total number of values in this region (Id.). Lee, therefore, teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Lee teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Lee, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Lee, p. 166, ll. 1-4 after Eq. (4)). Lee teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Lee teaches transforming an input signal where the transfer function is further selected as a ratio a calculated intermediate value (in this case, the local mean of the pixel values for a group of pixels including the input pixel) over a value that lies within a range bounded by definite limits. The following algorithm of Lee transforms the input pixel by subtracting the local mean from the value of the pixel, multiplying this difference by a gain k and adding the result to the local mean to provide the transformed pixel value $x'_{i,j}$: $x'_{i,j} = m_{i,j} + k(x_{i,j} - m_{i,j})$ where $k = \sqrt{\frac{v_{i,j}}{v_{orig}}}$ (Lee, p. 166, Equation (4)). In the above equation, $x_{i,j}$ represents the value of the input pixel and $m_{i,j}$ the local mean for the pixel at *(i,j)*. The calculation $x_{i,j} - m_{i,j}$ subtracts the local mean from the value of the pixel being processed. The local mean is an intermediate calculated value of a selected group of pixel values including the input pixel. (Lee, p.165, col. 2 last paragraph and p. 166, Equations (1) and (2)). The result of the subtraction operation is multiplied by a gain referred to as *k*. The gain *k* is defined as a ratio of a local standard deviation (i.e., square root of local variance of pixels in a group of pixels) to an original standard deviation (i.e., square root of original variance of pixels in a group of pixels). (Id). When the gain *k* is replaced with its definition in the above equation, the transformation function becomes:

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		$$x'_{i,j} = m_{i,j} + \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot x'_{i,j} - \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot m_{i,j}$$ The standard deviation (i.e., the square root of a variance) is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Lee, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local means value, $m_{i,j}$) over a value within a range of values (in this case, the original standard deviation).

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Claim Limitation	Polaroid Construction	Lee (1980)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph). "The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 8 is an obvious extension of Lee.

Claim Limitation	Polaroid Construction	Lee (1980)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	No construction is required. To the extent the court deems a construction necessary, *"determined constant"* should be construed to mean "chosen number."	Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a higher output pixel value than a lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

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Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Sabri (1985)

Claim Limitation	Polaroid Construction	Sabri (1985)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Sabri describes a system for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value."	**Function:** Sabri teaches using a block averaging means for receiving as input a plurality of pixel values and outputs an average value (i.e., an intermediate calculated value) for those pixels. (see Sabri, col. 3, lines 35-68). In Sabri, an apparatus has a summing means (Fig. 1 and Fig. 2, element 14) which computes and outputs an average value from received input pixel values. (Sabri, col. 3, lines 38-45). The summing means of Figure 1 serves to compute for a group of pixels a weighted average value according to the identified formula. (Sabri, col. 3, 38-47). This formula computes the sum of each luminance value for a series of successive luminance values in a region defined by column *n* and row *m*. (Id.) Each luminance value in the defined region is multiplied by a fractional weighting coefficient and summed to provide a weighted average value. This weighted average is an intermediate calculated value that is provided for the group of luminance values. Sabri, therefore, teaches a block averager as well as a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

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	Structure–a low pass filter or block average and equivalents thereof.	**Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies	**Function:** Sabri teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Sabri is an average of the pixel values preceding the pixel being processed. (Sabri, col. 2, ll. 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value, C_{ij}. (Sabri, col. 2, ll. 29-39). The contrast enhancement factor is then added to a calculation that includes the intermediate calculated value, i.e., the average φ of the pixels preceding the pixel being processed. Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the mean of the pixel values for a group of pixels preceding the pixel being processed) over a value that lies within a range bounded by definite limits. Sabri transforms an input signal using the transformation function, B_{ij}, $Bij = Yij + \left(\frac{1-2Yij}{R}\right)\phi ij$ (Sabri, col. 2, ll. 40-46). In the equation above ϕ_{ij}, is a weighted average of picture element values, which is the calculated intermediate value providing pixel information. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). R is the maximum range of input picture element values. (Sabri, col. 2, ll. 40-46). Following the substitution and multiplication of variables, the transfer function can be expressed as: $Bij = Yij + \frac{\phi ij - 2\times\phi ij\times Yij}{R}$ or $Bij = Yij + \frac{\phi ij}{R} - \frac{2\times\phi ij\times Yij}{R}$ Sabri, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which for Sabri is the average value of the pixels preceding the pixels being processed. Sabri also teaches transforming an input signal where the transfer function is further selected as

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of the average electronic information signal.	within the range of possible values", "*dynamic range of the electronic information signals*" should be construed to mean "value that lies within the range of possible values", "*average electronic information signal*" should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value" **Structure** $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	a ratio of the calculated intermediate value (the weighted average, ϕ_{ij}) over a value within a range of values (in this case, the maximum value of the dynamic range, *R*). **Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Sabri is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Sabri reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Sabri in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Sabri (1985)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Sabri teaches methods for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Sabri teaches computing for a pixel an average of luminance values of neighboring pixels. (Sabri, Abstract). The summing means of Figure 1 serves to compute, for a group of pixels, a weighted average according to the identified formula. (Sabri, col. 3, 38-47). This weighted average is an intermediate calculated value that provides pixel information. Therefore, Sabri teaches calculating an intermediate value for a selected group of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Sabri teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Sabri is an average of the pixel values preceding the pixel being processed. (Sabri, col. 2, ll. 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value, C_{ij}. (Sabri, col. 2, ll. 29-39). The contrast enhancement factor is then added to a calculation that includes the intermediate calculated value, i.e., the average φ of the pixels preceding the pixel being processed. Sabri, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which for Sabri is the average value of the pixels preceding the pixels being processed.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the mean of the pixel values for a group of pixels preceding the pixel being processed) over a value that lies within a range bounded by definite limits. Sabri transforms an input signal using the transformation function, B_{ij}, $Bij = Yij + \left(\frac{1-2Yij}{R}\right)\phi ij$ (Sabri, col. 2, ll. 40-46). In the equation above ϕ_{ij}, is a weighted average of picture element values, which is the calculated intermediate value providing pixel information. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). R is the maximum range of input picture element values. (Sabri, col. 2, ll. 40-46). Following the substitution and multiplication of variables, the transfer function can be expressed as: $Bij = Yij + \frac{\phi ij - 2\times\phi ij\times Yij}{R}$ or $Bij = Yij + \frac{\phi ij}{R} - \frac{2\times\phi ij\times Yij}{R}$ Therefore, Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (the weighted average, ϕ_{ij}) over a value within a range of values (in this case, the maximum value of the dynamic range, R).

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Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Rangayyan (1984)

Claim Limitation	Polaroid Construction	Rangayyan (1984)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Rangayyan describes a system for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to "0" and all six bits of the value equal to "1." Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value." **Structure**–a low pass filter or block average and equivalents thereof.	**Function:** Rangayyan describes using a block averager that receives as input a plurality of pixel values and outputs an intermediate calculated value representing an average for those pixels. (see Rangayyan, p. 561, col. 2, Section C, first paragraph). The average *a* is computed using a plurality of pixel values received as input. These plurality of pixels are the neighboring pixels forming a block (i.e., a matrix) centered around the pixel being processed. (Rangayyan, p. 561, col. 1, Section B, first paragraph). Therefore, Rangayyan teaches a block averager that receives as input a plurality of pixels and outputs an intermediate value for those pixels. **Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

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means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies within the range of possible values", *"dynamic range of the electronic information signals"* should be construed to mean "value that lies within the range of possible values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value"	**Function:** Rangayyan teaches selecting a transfer function based on the input pixel value and a calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, *a*. Rangayyan states that a contrast enhancement factor, *C*, is calculated using the value of the pixel being processed, *p*, and the average, *a*, of a group of pixels in the neighborhood around *p*. The contrast factor is used, as part of a final transformation equation, to transform each pixel value. Rangayyan teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value over a value that lies within a range bounded by definite limits. (Rangayyan, p. 561, Section C, Contrast Enhancement). Rangayyan computes a contrast measure *C* using the input pixel value, *p*, and the average value, *a*, of surrounding the values of the pixels: $C = \lvert p-a \rvert / (p+a)$ (Rangayyan, p. 561, col. 2). A new pixel value is calculated from the square root of *C*, referred to as *C'*, and the average *a* as follows: $p' = a \times (1+C')/(1-C')$ if $p \geq a$, and also $p' = a \times (1-C')/(1+C')$ if $p < a$ Expanding the transfer mathematically gives: $p' = a \times \frac{1+\sqrt{\frac{\lvert p-a \rvert}{(p+a)}}}{1-\sqrt{\frac{\lvert p-a \rvert}{(p+a)}}}$ for $p \geq a$, and $p' = a \times \frac{1-\sqrt{\frac{\lvert p-a \rvert}{(p+a)}}}{1+\sqrt{\frac{\lvert p-a \rvert}{(p+a)}}}$ for $p < a$ The transfer function *p'* is then used in a transformation function, *p"*, as follows: $p'' = 255 \times \frac{(p' - \min)}{\max - \min}$ for positive mode, $p'' = 255 \times \frac{(\max - p')}{(\max - \min)}$ for negative mode (Id.). Max refers to the maximum pixel value and min refers to the minimum pixel value. Replacing *p'* in this equation with its definition above gives: $p'' = 255 \times \frac{\left(a \times \frac{1+\sqrt{\lvert p-a \rvert / (p+a)}}{1-\sqrt{\lvert p-a \rvert / (p+a)}} \right) - \min}{\max - \min}$ for a positive and $p'' = 255 \times \frac{\max - \left(a \times \frac{1-\sqrt{\lvert p-a \rvert / (p+a)}}{1+\sqrt{\lvert p-a \rvert / (p+a)}} \right)}{\max - \min}$ for a negative mode.

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	Structure $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	The contrast measure *C*, which is the ratio of the absolute value of the difference $\|p - a\|$ over $(p+ a)$ is the calculated intermediate value providing pixel information. *max – min* represents a value within a range of possible values. Therefore, Rangayyan teaches selecting a transfer function for the pixel being processed using the value of the pixel and calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, *a*. Rangayyan also teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the contrast measure, C) over a value within a range of values (in this case, *max-min*). **Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Rangayyan is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Rangayyan reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Rangayyan in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Rangayyan (1984)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to "0" and all six bits of the value equal to "1." Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Rangayyan teaches calculating average pixel value of a group of pixels in a region surrounding the pixel being processed. (Rangayyan, p. 561, col. 2, Section C, first paragraph). Therefore, Rangayyan teaches calculating an intermediate value (in this case, an average) that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Rangayyan teaches selecting a transfer function based on the input pixel value and a calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, *a*. Rangayyan states that a contrast enhancement factor, *C*, is calculated using the value of the pixel being processed, *p*, and the average, *a*, of a group of pixels in the neighborhood around *p*. The contrast factor is used, as part of a final transformation equation, to transform each pixel value. Therefore, Rangayyan teaches selecting a transfer function for the pixel being processed using the value of the pixel and calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, *a*.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Rangayyan teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value over a value that lies within a range bounded by definite limits. (Rangayyan, p. 561, Section C, Contrast Enhancement). Rangayyan computes a contrast measure *C* using the input pixel value, *p*, and the average value, *a*, of surrounding the values of the pixels: $C = \|p-a\|/(p+a)$ (Rangayyan, p.561, col. 2). A new pixel value is calculated from the square root of *C*, referred to as *C'*, and the average *a* as follows: $p' = a \times (1+C')/(1-C')$ if $p \geq a$, and also $p' = a \times (1-C')/(1+C')$ if $p < a$ Expanding the transfer mathematically gives: $p' = a \times \frac{1+\sqrt{\frac{\|p-a\|}{(p+a)}}}{1-\sqrt{\frac{\|p-a\|}{(p+a)}}}$ for $p \geq a$, and $p' = a \times \frac{1-\sqrt{\frac{\|p-a\|}{(p+a)}}}{1+\sqrt{\frac{\|p-a\|}{(p+a)}}}$ for $p < a$ The transfer function *p'* is then used in a transformation function, *p"*, as follows: $p'' = 255 \times \frac{(p'-\min)}{\max-\min}$ for positive mode $p'' = 255 \times \frac{(\max-p')}{(\max-\min)}$ for negative mode (Id.).

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		Max refers to the maximum pixel value and min refers to the minimum pixel value. Replacing *p'* in this equation with its definition above gives: $p'' = 255 \times \frac{\left(a \times \frac{1+\sqrt{\lvert p-a \rvert / (p+a)}}{1-\sqrt{\lvert p-a \rvert / (p+a)}} \right) - \min}{\max - \min}$ for a positive and $p'' = 255 \times \frac{\max - \left(a \times \frac{1-\sqrt{\lvert p-a \rvert / (p+a)}}{1+\sqrt{\lvert p-a \rvert / (p+a)}} \right)}{\max - \min}$ for a negative mode. The contrast measure *C*, which is the ratio of the absolute value of the difference $\lvert p-a \rvert$ over $(p+a)$ is the calculated intermediate value providing pixel information. $max - min$ represents a value within a range of possible values. Therefore, Rangayyan teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the contrast measure, C. over a value within a range of values (in this case, *max-min*).

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Claim Limitation	Polaroid Construction	Rangayyan (1984)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $\|p\text{-}a\|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C*, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

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Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Chen(1987)

Claim Limitation	Polaroid Construction	Chen (1987)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Chen describes a system for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color,	**Function:** Chen teaches using a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Chen, col. 5, lines 25-50). The image filtering and enhancing circuit of Chen includes a pixel value averaging means. (Chen, col. 5., lines 25-26; Fig. 1, element 40). This averaging means computes and outputs an intermediate calculated value representing an average for a block of pixel values neighboring the pixel being processed. (Chen, col. 5, lines 35-42). Chen, therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. **Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

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	luminance, or chrominance value of calculated intermediate value." **Structure**–a low pass filter or block average and equivalents thereof.	
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be	**Function:** Chen teaches selecting a transfer function for each pixel based on the pixel value Chen teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a selected group of pixels in the neighborhood of the input pixel) over a value that lies within a range bounded by definite limits. Chen uses the following function to replace each input pixel value *I(i,j)* with an improved pixel value *I'(i,j)*: $$I'(i,j) = G(i,j) \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$ (Id.). *G(i,j)* refers to a gain function and $\overline{I(i,j)}$ is a mean of pixel values of neighboring pixels. Chen teaches that the transfer function *G(i,j)* may be expressed as: $$G(i,j) = \frac{\log(n) - \log(m)}{\log K(n) - \log K(m)}$$ in which *K(n)* and *K(m)* are average differences between the pixel at *(i,j)* and the values of the pixels lying within two circular areas having radius of *n* and *m*, respectively. Replacing the value of *G(i,j)* in the transform function $\overline{I(i,j)}$ with its expression, the equation becomes: $$I'(i,j) = \frac{\log(n) - \log(m)}{\log(K(n) - \log(K(m))} \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$ This same equation may be represented as: $$I'(i,j) = \frac{\{\log(n) - \log(m\} \times I(i,j)\}}{\log(K(n)) - \log(K(m))} - \frac{\{\log(n) - \log(m\} \times \overline{I(i,j)}\}}{\log(K(n)) - \log(K(m))} + \overline{I(i,j)}$$ Chen, therefore, teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the mean value, $\overline{I(i,j)}$, of pixels in the neighborhood of the input pixel) over a value within a range of values (in this case, the difference of the logarithmic value of the first average difference and the logarithmic value of the second average difference (i.e. *log(K(n))-log(K(m))*).

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that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	construed as "ratio of that calculated intermediate value over a value that lies within the range of possible values", "*dynamic range of the electronic information signals*" should be construed to mean "value that lies within the range of possible values", "*average electronic information signal*" should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value"	Chen also teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the mean value, $\hat{I}_{ij}$, of pixels in the neighborhood of the input pixel) over a value within a range of values (in this case, the difference of the logarithmic value of the first average difference and the logarithmic value of the second average difference (i.e. *log(K(n)-log(K(m))*.
	Structure $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	**Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Chen is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Chen reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Chen in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Chen (1987)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Chen teaches methods for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Chen teaches computing the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Chen, Abstract, 10-13). The image enhancing circuit (Chen, Fig. 1, element C) of Chen includes a pixel value averaging means (Chen Fig. 1, element 40) to generate a mean pixel value. (Chen, col. 5, ll. 25-27). By way of example in Figure 2, a mean value is computed to represent the average of 25 pixel values in a 5 by 5 neighborhood centered around a pixel being processed. (Chen, col. 5, ll. 39-42). This average is a calculated intermediate value and is provided for the group of pixels of the surround region. Chen, therefore, teaches a calculated intermediate value (in this case, an average) for each group of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Chen teaches selecting a transfer function for each pixel based on the pixel value and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Abstract, Chen). A transfer function provides an improved pixel value by subtracting the mean neighborhood value from the value of the pixel. (Chen, col. 8, l-11; Eq. 11). This difference between the pixel value and the intermediate calculated value is multiplied by a transfer function. (Id.). Therefore, Chen teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Chen teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a selected group of pixels in the neighborhood of the input pixel) over a value that lies within a range bounded by definite limits. Chen uses the following function to replace each input pixel value *I(i,j)* with an improved pixel value *I'(i,j)*: $$I'(i,j) = G(i,j) \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$ (Id.). *G(i,j)* refers to a gain function and $\overline{I(i,j)}$ is a mean of pixel values of neighboring pixels. Chen teaches that the transfer function *G(i,j)* may be expressed as: $$G(i,j) = \frac{\log(n) - \log(m)}{\log K(n) - \log K(m)}$$ in which *K(n)* and *K(m)* are average differences between the pixel at *(i,j)* and the values of the pixels lying within two circular areas having radius of *n* and *m*, respectively. Replacing the value of *G(i,j)* in the transform function $\overline{I(i,j)}$ with its expression, the equation becomes: $$I'(i,j) = \frac{\log(n) - \log(m)}{\log(K(n)) - \log(K(m))} \times \{I(i,j) - \overline{I(i,j)}\} + \overline{I(i,j)}$$

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		This same equation may be represented as: $$I'(i,j)=\frac{\{\log(n)-\log(m\}\times I(i,j)\}}{\log(K(n))-\log(K(m))}-\frac{\{\log(n)-\log(m\}\times \overline{I(i,j)}\}}{\log(K(n))-\log(K(m))}+\overline{I(i,j)}$$ Chen, therefore, teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the mean value, $\overline{I(i,j)}$, of pixels in the neighborhood of the input pixel) over a value within a range of values (in this case, the difference of the logarithmic value of the first average difference and the logarithmic value of the second average difference (i.e. *log(K(n))-log(K(m))*)..

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Polaroid Construction:

Claims 1-3 and 7-9 of the '381 Patent in view of Narendra (1981)

Claim Limitation	Polaroid Construction	Narendra (1981)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Narendra describes a system for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p. 656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value."	**Function:** Narendra teaches using a low-pass filter that receives as input a plurality of pixels and outputs an intermediate value for those pixels. (see Narendra, p.657, col. 2, first full paragraph). Narendra teaches implementing the local average function identified in Figure 2 as a low-pass filter ("LPF") as identified in Figure 4. The local average function is computed on a local area surrounding the pixel. (Narendra, p.656, col. 2, first full paragraph). Thus, Narendra, teaches a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixel values.

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	Structure–a low pass filter or block average and equivalents thereof.	**Structure:** As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies within the range of possible values", *"dynamic*	**Function:** Narendra teaches selecting a transfer function for the pixel being processed based on the pixel value and the calculated intermediate function which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed. (Narendra, p. 656. Section II, paragraph 5). In the transformation formula of Equation 1, this intermediate calculated value is subtracted from the pixel value. (Narendra, p. 656, col. 2, Eq. 1). This difference is multiplied by a variable gain function. Narendra teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a local group of pixels M_{ij}) over a value that lies within a range bounded by definite limits. The transformation function referred to as $\hat{I}_{ij}$ uses the pixel value I_{ij} of the pixel being processed and a mean value M_{ij}. (Id.) $\hat{I}_{ij} = G_{ij}(I_{ij} - M_{ij}) + M_{ij}$ (see Narendra, p. 656, Equation (1)). The local mean value M_{ij} is an intermediate calculated value computed on a group of pixels surrounding the pixel being processed. (Narendra, p. 65, first paragraph). The transformation function takes the difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}. $G_{ij} = \alpha \frac{M}{\sigma_{ij}}$, $0 < \alpha < 1$ (Id.) When the gain G_{ij} is replaced with its definition in the above equation, the transformation function becomes: $\hat{I}_{ij} = \alpha \frac{M}{\sigma_{ij}} \cdot I_{ij} - \alpha \frac{M}{\sigma_{ij}} \cdot M_{ij} + M_{ij}$ which, in turn, becomes: $\hat{I}_{ij} = \frac{\alpha \cdot M \cdot I_{ii}}{\sigma_{ij}} - \frac{\alpha \cdot M \cdot M_{ii}}{\sigma_{ij}} + M_{ij}$ Where σ_{ij} is the standard and deviation of local pixel values.

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of the average electronic information signal.	*range of the electronic information signals*" should be construed to mean "value that lies within the range of possible values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value" **Structure** $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	Therefore, Narendra teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed. Narendra also teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the local mean value, M_{ij}) over a value within a range of values (in this case, a standard deviation value). **Structure:** Gonzalez teaches such an algorithm. In the Gonzalez algorithm of Appendix A, an exponent for a transfer function referred to as SS is selected based on a ratio of a calculated intermediate value (ALOG(FH/T)) divided by 32, which is a value in the dynamic range of the device to process the image (i.e., the printer). (see Gonzalez, p. 454, see computation of variable SS). This transfer function outputs a value (i.e., a gamma value) by raising a constant value to a power of the ratio (i.e., the calculated intermediate value divided by a value in the dynamic range). The Gonzalez algorithm further transforms the input pixel by the function listed as FLEV on the line labeled 140. (Id.) This function transforms the input pixel by computing an exponent of the gamma value generated by the transfer function, which is selected based on the above-identified ratio. Therefore, Gonzalez, provides an algorithm that modifies a transform function using a power factor, γ, that is the result of a ratio of a calculated intermediate value divided by any value within the dynamic range (in this case, the value of (ALOG(FH/T)). It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Rangayyan is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Rangayyan reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Rangayyan in combination with Gonzalez algorithm.

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Claim Limitation	Polaroid Construction	Narendra (1981)
2. The system of claim 1 herein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, α, with the mean value of the neighboring pixels so that gain would increase in areas of low light or high light. Therefore, I believe claim 2 is obvious in view of Narendra.

Claim Limitation	Polaroid Construction	Narendra (1981)
3. The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.	No proposed construction.	Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by mulitplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 3 is obvious in view of Narendra.

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Claim Limitation	Polaroid Construction	Narendra (1981)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Narendra teaches methods for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p. 656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Narendra teaches calculating a local mean for a pixel, referred to as M_{ij}, for a local area surrounding the pixel. (p. 656, col. 2, ll. 3-6). Narendra, therefore, teaches an intermediate calculated value (in this case, a mean) for each group of pixels that provides pixel information.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Narendra teaches selecting a transfer function for the pixel being processed based on the pixel value and the calculated intermediate function which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed. (Narendra, p. 656. Section II, paragraph 5). In the transformation formula of Equation 1, this intermediate calculated value is subtracted from the pixel value. (Narendra, p. 656, col. 2, Eq. 1). This difference is multiplied by a variable gain function. Therefore, Narendra teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Narendra teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a local group of pixels M_{ij}) over a value that lies within a range bounded by definite limits. The transformation function referred to as $\hat{I}_{ij}$ uses the pixel value I_{ij} of the pixel being processed and a mean value M_{ij}. (Id.) $\hat{I}_{ij} = G_{ij}(I_{ij} - M_{ij}) + M_{ij}$ (see Narendra, p. 656, Equation (1)). The local mean value M_{ij} is an intermediate calculated value computed on a group of pixels surrounding the pixel being processed. (Narendra, p. 65, first paragraph). The transformation function takes the difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}. $G_{ij} = \alpha \frac{M}{\sigma_{ij}}$, $0 < \alpha < 1$ (Id.) When the gain G_{ij} is replaced with its definition in the above equation, the transformation function becomes: $\hat{I}_{ij} = \alpha \frac{M}{\sigma_{ij}} \cdot I_{ij} - \alpha \frac{M}{\sigma_{ij}} \cdot M_{ij} + M_{ij}$ which, in turn, becomes: $\hat{I}_{ij} = \frac{\alpha \cdot M \cdot I_{ij}}{\sigma_{ij}} - \frac{\alpha \cdot M \cdot M_{ij}}{\sigma_{ij}} + M_{ij}$

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		Where σ_{ij} is the standard deviation of local pixel values. Therefore, Narendra teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the local mean value, M_{ij}) over a value within a range of values (in this case, a standard deviation value).

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Claim Limitation	Polaroid Construction	Narendra (1981)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, M, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor taught by Narendra to further increase the content of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of image using the mean value of the neighboring pixels. In this matter the gain would increase in areas of low light or high light. Therefore, I believe claim 8 is obvious in view of Narendra.

Claim Limitation	Polaroid Construction	Narendra (1981)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	No construction is required. To the extent the court deems a construction necessary, *"determined constant"* should be construed to mean "chosen number."	Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by multiplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Narendra.

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Claim Limitation	Polaroid Construction	Gonzalez algorithm (1987)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**–averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged **Terms used to describe the function:** *"averaging"* should be construed to mean "calculating an intermediate value for", *"average"* should be construed to mean "of calculated intermediate value" , *"electronic information signals"* should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of calculated intermediate value." **Structure**--a low pass filter or block average and equivalents thereof.	Means for averaging electronic information signals is well-known and is taught by Gonzalez. (Gonzalez, p. 160) Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25).

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Claim Limitation	Polaroid Construction	Gonzalez algorithm (1987)
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	**Function**–"selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal." **Terms used to describe the function:** *"transfer function"* should be construed to mean function that transforms an input signal, *"electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value", *"ratio of the value of the average electronic information signal to the dynamic range of the electronic information signal"* should be construed as "ratio of that calculated intermediate value over a value that lies within the range of possible values", *"dynamic range of the electronic information signals"* should be construed to mean "value that lies within the range of possible values", *"average electronic information signal"* should be construed to mean "signal providing pixel information, such as a color, luminance, or chrominance value of	The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, I, into an output pixel value FLEV as follows: FLEV = FH* EXP(SS*(GN-I)) + 0.5 (Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (FH/T) over a value in the range of values because the function SS is computed as follows: SS = (-1/GN) * ALOG (FH/T) (Gonzalez, p. 454, see computation of variable SS). GN represents the maximum value of the intended output device. GN therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, I, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (FH/T) over a value in the range of values (in this case, GN).

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Claim Limitation	Polaroid Construction	Gonzalez algorithm (1987)
	calculated intermediate value" **Structure** $Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}$, where $\gamma = (1 + C)(Av/M - 1)$, where Y_{OUT} is the transformed signal providing pixel information, such as a color, luminance, or chrominance value, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, such as a color, luminance, or chrominance value, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range, and equivalents thereof.	

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Claim Limitation	Polaroid Construction	Gonzalez Algorithm (1987)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	The Gonzalez algorithm teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value for each of the group of pixels. The Gonzalez algorithm computes a calculated intermediate value for a group of pixels using the following function, SS: SS=(-1/GN) * ALOG (FH/T) GN contains a value of 32, representing the maximum value of the dynamic range of the intended output device (in this case, a line-printer). FH represents the maximum gray level value of the group of pixels representing the input image. (Gonzalez, p. 453, line 4). T represents the minimum gray level of the group of pixels representing the input image (Gonzalez, p. 453, line 3). The Gonzalez algorithm therefore, teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value . In this case, a logarithmic function, ALOG, of the ratio of FH to T.

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	The Gonzalez algorithm teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which in this case, ALOG (FH/T). The Gonzalez algorithm provides the following transfer function: FLEV = FH* EXP(SS*(GN-I)) + 0.5 (Gonzalez, p. 454, see computation of variable SS). I represents the input pixel value. GN represents the maximum value of the dynamic range of the intended output device. SS is a function computed as follows: SS = (-1/GN) * ALOG (FH/T) (Gonzalez, p. 454, see computation of variable SS). Gonzalez, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel I, and the calculated intermediate value, ALOG (FH/T).
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, I, into an output pixel value FLEV as follows: FLEV = FH* EXP(SS*(GN-I)) + 0.5 (Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (FH/T) over a value in the range of values because the function SS is computed as follows: SS = (-1/GN) * ALOG (FH/T) (Gonzalez, p. 454, see computation of variable SS). GN represents the maximum value of the intended output device. GN, therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, I, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (FH/T) over a value in the range of values (in this case, GN).

APPENDIX K

Polaroid Construction:

Claims 7-9 of the '381 Patent in view of Wang (1983)

Claim Limitation	Polaroid Construction	Wang (1983)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	"electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" "each signal being associated with a value that lies within a range of possible values bounded by definite limits"	Wang teaches digital enhancement techniques to improve picture quality. (Wang, p. 363, Introduction, line 1). Wang defines an image as a collection of pixels, each pixel at a coordinate x and y in a rectangular representation of an image. (Wang, p. 365, Section 2. Notation; Figures (4-1), (4-2) and (4-3)). Each of the pixels has a value representing a gray level that lies within a minimum and a maximum gray level of the image. (Wang, p. 365, Section 2, Notation). Thus, the value of a pixel lies within a range of possible values defined by the bounds of a minimum value and a maximum value. Each pixel is processed sequentially. (Wang, Eq. 6-4). Therefore, Wang teaches successive transformation of luminance image data defining an original image, each luminance signal having an associated luminance value that lies within a range of possible values that is bounded by definite limits.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels	Wang teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Wang, p.367, first paragraph). Wang takes an average (i.e., an intermediate calculated value) over a rectangular neighborhood surrounding the pixel being processed. (Id.; Equation (4-1) and (4-2)). Therefore, Wang also teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels

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selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel	Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4 after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* value within the range of possible values	Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4 after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

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Claim Limitation	Polaroid Construction	Wang (1983)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	"average" should be construed to mean "of calculated intermediate value." "average electronic information signal" should be construed to mean "signal providing pixel information, such as color, luminance, or chrominance value of calculated intermediate value."	Wang teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Wang teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Wang, p. 166, col. 1, last paragraph). "The linear function ... yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increases the "stretch" in areas of very low light or very high light, because that would allow Wang to further increase contrast at both ends of the gray scale.

Claim Limitation	Polaroid Construction	Wang (1983)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	No construction is required. To the extent the court deems a construction necessary, *"determined constant"* should be construed to mean "chosen number."	Wang teaches using the contrast gain factor of a constant k as also taught by Lee. (Wang, p. 376, Equation (6-4)). As in Lee, Wang teaches that a constant k is multiplied by the difference between the value of the pixel itself g(x,y) and the mean value of the pixels surrounding this pixel, $\bar{g}(x,y)$. A higher value of k results in a higher output pixel value than will result using lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Wang, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Wang.

APPENDIX L

Claim Limitation	HP Construction	Richard (1987)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	an uninterrupted stream of received luminance image data [pixels] defining an original image to be recorded signal(s) providing luminance pixel information each received pixel has an associated luminance value that lies within a predetermined group of luminance values dynamic range: an integer representing the number of possible pixel values; for an 8-bit system, 256	Richard teaches methods for receiving and continuously enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Richard teaches that a sequence of numerical pixel values representing luminance are received. (Richard, col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will lie within a predetermined group of luminance values. Richard further teaches that the system has an output terminal for delivering a sequence of numerical pixel values of luminance having enhanced contrast. (Richard, col. 2, ll. 24-25). The output values produced by Richard could be sent to a computing device for storage on, for example, a disk drive. Therefore, Richard teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that may be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express the luminance value.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	Averaging: taking an arithmetic mean of or an arithmetic mean	Averaging electronic information signals is well-known and is taught by Richard. (Richard, col. 2. ll. 19-21) Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25).

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Claim Limitation	HP Construction	Richard (1987)
selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	each input pixel value that has been part of the averaging step is altered based on the corresponding average electronic information signal to which it is associated and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing a select proportionate value of the dynamic range of the average electronic information signals.	Richard teaches that each input pixel has a transfer function selected based on its pixel value and the average of local mean, Mv, which includes the input pixel value. Richard teaches "means for multiplying the value of luminance of the point being processed by a variable coefficient which is proportional to the ratio Mv/Mg" (Richard, col. 1, lines 66-68). Mv is an average of luminance values of points which are adjacent to, and include, the pixel being processed for contrast enhancement. (Richard, col. 2, lines 19-22). Richard teaches that an input pixel value is transformed according to the following function: Yij(Mv/Mg)*K The transfer function in Richard is, therefore, dependent on the input pixel value, Yij, and the average value of neighboring pixels (including the input pixel value), Mv.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* any value within the determinate dynamic range of values, selected depending on where the least image enhancement is desired.	Richard teaches altering an input signal using the pixel value itself, an arithmetic mean of the value of a group of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean associated with the pixel group by an integer value within a range of values that represent the dynamic range. The transformation function depicted as element 5 in Figure 1 of Richard alters an input signal by multiplying the value of the pixel, Yij, by the ratio of the local mean value of nearby pixels, Mv, to the global mean value of the image, Mg, and further multiplies that by a constant K. (Richard, Figure 1, elements 10-14). Therefore, Richard teaches that a pixel's value is altered based on the starting value of the pixel, Yij, and based on the result of dividing the local average, Mv, by a select proportionate value of the dynamic range, Mg. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Further, because Richards teaches a represented by a finite number of bits. (See, e.g., FIG. 1 of Richard in which Mg is the output of a ROM memory element). Richard, therefore, teaches altering an input signal using the pixel value itself, an arithmetic mean of a group of values of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean of a group of values of pixels associated with the pixel by a value within a range of values that represent the dynamic range.

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Claim Limitation	HP Construction	Richard (1987)
8. The method claim 7 wherein the transfer function is selected: in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	**Indefinite Terms:** low scene light intensity levels, lowest scene light intensity levels, high scene light intensity levels, highest scene light intensity levels	Richard teaches selecting a transfer function to provide higher contrast for a pixel when the calculated arithmetic mean represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio Mv /Mg. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of Mv/Mg will be very close to 0 (for very dark pixels) and will be greater than one for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for the darkest pixels as compared to less dark pixels and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for the lighter pixels as compared to less light pixels. Richard, therefore, teaches selecting the transfer function to provide higher contrast within the dark and light regions of an image.

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Claim Limitation	HP Construction	Richard (1987)
9. The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.	**Indefinite terms:** areas of higher contrast *determined constant*: a control parameter	Richard teaches a system in which a constant value, K, can be determined by an operator to increase the contrast in areas of higher contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Yij multiplied by (Mv/Mg), and further multiplied by this constant K. (Richard, Fig. 1) An increase in K will increase the contrast between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the lightest areas of an image and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

APPENDIX M

Claim Limitation	HP Construction	Sabri (1982)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	an uninterrupted stream of received luminance image data [pixels] defining an original image to be recorded signal(s) providing luminance pixel information each received pixel has an associated luminance value that lies within a predetermined group of luminance values dynamic range: an integer representing the number of possible pixel values; for an 8-bit system, 256	Sabri teaches systems and methods for enhancing the quality of video images, which are electronic image data, originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function**– providing an average for selected pixel values around one pixel, where the average is correlated to each pixel making up the average. Averaging: taking an arithmetic mean of or an arithmetic mean **Structure**– a block averager 12 with a buffer memory that takes luminance as an input and outputs an average luminance value that is correlated to each pixel in the block, and equivalents thereof.	Means for averaging electronic information signals is well-known and is taught by Sabri. (Sabri, col. 2. ll. 19-26) Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25).

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Claim Limitation	HP Construction	Sabri (1982)
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	**Function:** selecting a transfer function for each incoming pixel based on the pixel value and its corresponding average electronic information signal, and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing the dynamic range of the average electronic information signals. **Structure** none (*indefinite*), alternatively: a gamma determining circuit 14 containing a multiplier circuit 18, a combining circuit 20, a second combiner circuit 22, a log circuit 24, a multiplier circuit 26 and a antilogarithmic determining circuit 28 – all arranged according to Fig 4, which computes gamma based on the formula (1)(1) - g = $\div C\, Av\, M$, where Av is average luminance of the input, C is a constant and M equals one half of the dynamic range. And the transfer function imposing circuit 16 containing a logarithm determining circuit 30, a combiner circuit 32, a multiplier circuit 34, a second combiner circuit 36 and an antilogarithm determining circuit 38 – all arranged according to Fig 4, which computes an output luminance: $Y_{OUT} = Y_{MAX}(Y_{IN}\ Y_{MAX})^{\gamma}$, where Y_{OUT} is the output luminance value, Y_{MAX} is the maximum value in the dynamic range (255), Y_{IN} is the input pixel value, and g is the "means for selecting a transfer function" and equivalents.	**Function:** Sabri teaches selecting a transfer function using the pixel value itself and the calculated arithmetic mean for the group of pixels that includes and neighbors the subject pixel and also based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals. (Sabri, Fig. 1). The value of the transformation function Bij is computed from an average referred to as φ and a contrast enhancement factor referred to as γij. (Sabri, col. 2, lines 40-46). The contrast enhancement factor is derived from the input video signal, Cij. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, φ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, φ, is divided by the maximum range, R, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches using a function that transforms an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that mean by the dynamic range of a value equal to the electronic information signals.

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Claim Limitation	HP Construction	Sabri (1982)
7. A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising:	an uninterrupted stream of received luminance image data [pixels] defining an original image to be recorded signal(s) providing luminance pixel information each received pixel has an associated luminance value that lies within a predetermined group of luminance values dynamic range: an integer representing the number of possible pixel values; for an 8-bit system, 256	Sabri teaches systems and methods for continuously enhancing the quality of video image data originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.
averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;	Averaging: taking an arithmetic mean of or an arithmetic mean	Averaging electronic information signals is well-known and is taught by Sabri. (Sabri, col. 2. ll. 19-26) Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25).

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Claim Limitation	HP Construction	Sabri (1982)
selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and	each input pixel value that has been part of the averaging step is altered based on the corresponding average electronic information signal to which it is associated and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing a select proportionate value of the dynamic range of the average electronic information signals.	Sabri teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel. (Sabri, col. 2, lines 4-14). A contrast enhancement factor γij is derived from the pixel value itself, Cij. (Sabri, col. 2, lines 29-39). The contrast enhancement factor is then added to a calculation that includes the average, φ, of the values of the pixel and the pixels preceding the pixel being processed. (Sabri, col. 2, lines 40-46). Sabri, therefore, teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel.
transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	transforming the signal providing pixel information, such as a color, luminance, or chrominance value corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value" *Select proportionate value:* any value within the determinate dynamic range of values, selected depending on where the least image enhancement is desired.	Sabri teaches altering an input signal using the pixel value, the calculated arithmetic mean for the group of pixels neighboring including the subject pixel (?) and is based on the result of dividing the calculated arithmetic mean by an integer value within a range of values that represent the dynamic range. (Sabri, Fig. 1). The value of the transformation function Bij is computed from an average referred to as φ and a contrast enhancement factor referred to as γij. (Sabri, col. 2, lines 40-46). The contrast enhancement signal is derived from the input video signal, Cij. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, φ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, φ, is divided by the maximum range, R, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches altering an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that calculated arithmetic mean by an integer value within a range of values that represent the dynamic range.

APPENDIX N

Claim Limitation	HP Construction	Rangayyan (1984)
1. A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:	an uninterrupted stream of received luminance image data [pixels] defining an original image to be recorded signal(s) providing luminance pixel information each received pixel has an associated luminance value that lies within a predetermined group of luminance values dynamic range: an integer representing the number of possible pixel values; for an 8-bit system, 256	Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels received via acquisition devices, the pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Since each pixel value in Rangayyan is a number expressed as six bits, every pixel value will lie within a predetermined group of luminance values. Therefore, Rangayyan teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.
means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;	**Function–** providing an average for selected pixel values around one pixel, where the average is correlated to each pixel making up the average. Averaging: taking an arithmetic mean of or an arithmetic mean **Structure–** a block averager 12 with a buffer memory that takes luminance as an input and outputs an average luminance value that is correlated to each pixel in the block, and equivalents thereof.	Means for averaging electronic information signals is well-known and is taught by Rangayyan. (Rangayyan, Section C., paragraph 1) Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25).
means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal	**Function:** selecting a transfer function for each incoming pixel based on the pixel value and its corresponding average electronic information signal, and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing the dynamic range of the average electronic information signals. **Structure**	**Function:** Rangayyan teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing that mean by a value equal to the dynamic range of the electronic information signals. (Rangayyan, p. 561, Section C. Contrast Enhancement). Rangayyan teaches that the first step in transforming an input pixel value is to calculate a contrast measure, C. The value of C is arrived at by dividing the absolute value of the difference between the input pixel value, p, and the average value, a, of pixels surrounding the input pixel, $\|p - a\|$, by (p+ a). (Rangayyan, p.561, col. 1, Equation for $C = \|p - a\|/(p+ a)$). The square root of the contrast factor, C, is calculated, C', and then used in a selected transfer function $p' = a(1+C')/(1-C')$,

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Claim Limitation	HP Construction	Rangayyan (1984)
for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.	none (*indefinite*), alternatively: a gamma determining circuit 14 containing a multiplier circuit 18, a combining circuit 20, a second combiner circuit 22, a log circuit 24, a multiplier circuit 26 and a antilogarithmic determining circuit 28 – all arranged according to Fig 4, which computes gamma based on the formula (1)(1) - g = $+C\,Av\,M$, where Av is average luminance of the input, C is a constant and M equals one half of the dynamic range. And the transfer function imposing circuit 16 containing a logarithm determining circuit 30, a combiner circuit 32, a multiplier circuit 34, a second combiner circuit 36 and an antilogarithm determining circuit 38 – all arranged according to Fig 4, which computes an output luminance: $Y_{OUT} = Y_{MAX}(Y_{IN}\,Y_{MAX})^{y}$, where Y_{OUT} is the output luminance value, Y_{MAX} is the maximum value in the dynamic range (255), Y_{IN} is the input pixel value, and g is the "means for selecting a transfer function" and equivalents.	when p>=a or p'= a(1-C')/(1+C'), when p<a. A new pixel value is then computed from p' using one of the following equations: p"=255(p'-min)/(max-min); or p"=255(max-p')/(max-min). The value of max represents the maximum pixel value and the value of min represents the minimum pixel value; (max-min) represents, therefore, the maximum dynamic range of the image. Rangayyan, therefore, teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals.

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Claim Limitation	HP Construction	Rangayyan (1984)
2. The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.	**Indefinite Terms:** low scene light intensity levels, lowest scene light intensity levels, high scene light intensity levels, highest scene light intensity levels	Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure C calculates the difference between the pixel value itself and the neighborhood average |p-a|. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, C, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function p' will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

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Claim Limitation	HP Construction	Rangayyan (1984)
3. The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.	**Indefinite terms:** areas of higher contrast *determined constant*: a control parameter	Gain factors are well-known in the art, see, e.g., Gonzalez, Richard, Lee, Sabri, Narendra and Wang. Gonzalez teaches that the transfer function is computed with a determined constant k, which is determined to be a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). Richard teaches a system in which a constant value, K, can be determined by an operator to control the contrast. (Richard, col. 5, lines 55-58). Lee teaches an algorithm in which the new pixel value, x'i,j , is equal to the local mean, mi,j plus the input pixel value minus the local mean, xi,j-mij, multiplied by a determined gain factor, k. (Lee, p.166, col. 1, Eq. 4). Chen teaches using a constant k for adjusting the contrast calculated by the selected transfer function. (Chen, col. 1, lines 22-49). Sabri teaches using determined constants to derive a selected transfer function for performing transformation of a pixel value. (Sabri, col. 2, lines 29-39). Narendra teaches a transfer function using a locally adaptive gain factor based on a determined constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor Gij is calculated by mulitplying a determined constant value referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. Wang teaches using the contrast gain factor of a determined constant k as also taught by Lee. (Wang, p. 376, Equation (6-4)).

EXHIBIT 5

REDACTED

EXHIBIT 6

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION, Plaintiff, v. HEWLETT-PACKARD COMPANY, Defendant.	)	C.A. No. 06-783 (SLR)

ERRATA TO EXPERT REPORT OF DR. RANGARAJ RANGAYYAN

I, Dr. Rangaraj Rangayyan, submit the following corrections to my initial Expert Report submitted on March 14, 2008. Please replace paragraphs numbered 7, 81, 195, 200, 201, 202, 203, 256 and 257 in my initial Expert with its corresponding numbered paragraph below.

7. I have given many lectures, research seminars, and tutorials on digital image processing, medical imaging and image analysis, biomedical signal analysis, and related topics, and collaborated with researchers at universities, institutes, and research organizations in India, Canada, the United States, Brazil, Argentina, Uruguay, Chile, the United Kingdom, Russia, The Netherlands, Egypt, France, Spain, Italy, Romania, Malaysia, Singapore, Thailand, Japan, Hong Kong, and China.

81. As a survey article, Wang shows that different techniques for image processing use similar constituent parts to achieve contrast enhancement and that those parts are often used, or are attempted to be used, interchangeably. Although I cite specific sections of Wang in this

report, the entire article reflects common knowledge at the time the application for the '381 patent was filed. I may, therefore, rely generally on Wang to support my testimony.

195. Wang teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. In Eq. 6-4 on p376, the gain factor *k* is multiplied with the difference between the pixel being processed and the local mean; the result is added to the local mean. The transfer function depends upon the local mean or luminance. Because the difference between the pixel being processed and the local mean is used to derive the output, the method provides higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition. Wang explains that "if $k>1$, the difference between the local mean and gray level at (x, y) is magnified". Therefore, Wang teaches a method for image enhancement where the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition.

200. Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function $g(x,y)$ applies a local gain factor $A(x,y)$ to the difference between the pixel value being processed $f(x,y)$ and the local mean $m(x,y)$ of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor $A(x,y)$ amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of

pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

201. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}-m_{ij}$, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a larger portion of the difference between the pixel being processed and the local mean being applied to the output. This leads to a larger local difference or contrast. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Lee.

202. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by multiplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain value results in a larger portion of the difference between the pixel being processed and the local mean being applied to the output. This leads to a larger local difference or contrast. Therefore, Narendra teaches a system where increasing a

constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Narendra.

203. Wang teaches using the contrast gain factor of a constant *k* as also taught by Lee. (Wang, p. 376, Equation (6-4)). As in Lee, Wang teaches that a constant *k* is multiplied by the difference between the value of the pixel itself g(x,y) and the mean value of the pixels surrounding this pixel, $\breve{g}(x,y)$. A higher value of *k* results in a larger portion of the difference between the pixel being processed and the local mean being applied to the output. This leads to a larger local difference or contrast. Therefore, Wang teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Wang.

256. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, *k*. (Lee, p.166, col. 1, Eq. 4). A higher value of *k* results in a larger portion of the difference between the pixel being processed and the local mean being applied to the output. This leads to a larger local difference or contrast. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Lee.

257. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by multiplying a constant value, referred to as α, by the global mean (M) of the image brightness

divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain value results in a larger portion of the difference between the pixel being processed and the local mean being applied to the output. This leads to a larger local difference or contrast. Therefore, Narendra teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Narendra.

RMR

Rangaraj Rangayyan, Ph.D.

EXHIBIT 7

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